734

FINAL REPORT

FOR

SIMPLIFIED ZERO GRAVITY AMMONIA

FEED SYSTEM PROGRAM

Contract No. NAS 5-21010

May 1970

Prepared by

TRW, Inc.
TRW Systems Group
One Space Park
Redondo Beach, California

For

Goddard Space Flight Center
Greenbelt, Maryland

FINAL REPORT

FOR

SIMPLIFIED ZERO GRAVITY AMMONIA

FEED SYSTEM PROGRAM

Contract No. NAS 5-21010

May 1970

Goddard Space Flight Center

Contracting Officer: J. A. Maloney

Technical Officer: D. I. Asato

Prepared by

TRW, Inc.

TRW Systems Group

One Space Park,

Redondo Beach, California

Project Manager: W. F. Krieve

For

Goddard Space Flight Center

Greenbelt, Maryland

ABSTRACT

This report describes the development and testing of a pneumatic-regulated ammonia propellant feed system for spacecraft applications. The system developed for the program consisted of a propellant storage tank, a capillary tube heat exchanger bonded to the tank wall, a pneumatic pressure regulator, and a plenum tank. It was designed to operate in a zero gravity environment. Under this condition, either liquid or vapor phase ammonia could be expelled from the storage tank; however, only vapor phase ammonia would be delivered to the propellant distribution system within a regulated pressure bandwidth. The feed system was assembled and subjected to a one-month demonstration test, which included operation over a range of ambient temperatures, flow rates, flow ON times and duty cycles. All tests were operated at a nominal propellant delivery pressure at 20 psia within an ambient temperature range of 20°F to 100°F. Steady-state propellant flow rates were in the range of 3×10^{-5} to 1×10^{-3} lb/sec. Operation in the pulse flow mode was performed with duty cycles of 1 to 3 percent and flow ON-times of 50 to 300 milliseconds with flow rates during a pulse of 5×10^{-4} to 1×10^{-3} lb/sec. All tests were performed with liquid and vapor phase ammonia leaving the storage tank. The system exhibited the capability of maintaining a delivered pressure within a $\pm$ 5 percent bandwidth for all test flow conditions above 40°F. The upper level of the bandwidth increased to approximately 10 percent during pulsed operation with flow ON times of 300 milliseconds at temperatures below 40°F. This effect could be circumvented by increasing the system plenum volume. During all of these tests, the delivered propellant phase was vapor. The system demonstrated design simplicity and performance capability similar to those of high pressure gas systems, but with the weight advantages of ammonia.

TABLE OF CONTENTS

TABLE OF CONTENTS, Cont'd.

APPENDICES

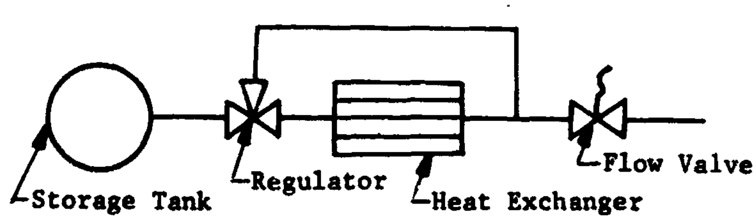
ILLUSTRATIONS

LIST OF TABLES

1. INTRODUCTION AND SUMMARY

An ammonia feed system intended for zero-gravity spacecraft applications has been designed, fabricated and tested under Goddard Space Flight Center Contract NAS 5-21010. Ammonia is a storable liquid propellant with only a moderate vapor pressure and has a lower molecular weight than most of the gases used in high storage pressure systems. Because of ammonia's high storage density at low pressures and high total impulse per unit weight, ammonia propellant systems are considerably lighter than high pressure gas systems. The object of this program was to utilize the advantages of ammonia propellant in a feed system that was comparable in design simplicity to a high pressure gas system.

The ammonia feed system consisted of a propellant storage tank, a capillary tube heat exchanger bonded to the tank, and a pneumatic pressure regulator. Since either liquid or vapor phase ammonia could be exhausted from the storage tank in a zero-gravity environment, the regulator/capillary tube assembly controls both the propellant delivery pressure and the delivered propellant phase. Although the pneumatic pressure regulator can accept either liquid or vapor phase ammonia from the storage tank, the capillary tubes insure that only vapor phase ammonia is supplied to the propellant distribution system. The capillary tubes are sized so that they have sufficient heat transfer area with minimum volume for complete liquid vaporization under all flow conditions. A system schematic is sketched below:



The use of a regulator for flow control represents a simplification of the ammonia feed system developed for the Air Force under Contract No. AF33(615)-3729 and reported in Reference 1. The referenced system utilized a valve actuated by a transducer through an electronic switch for flow control.

The pneumatically-regulated system was charged with ammonia and operated for a one-month period at various propellant flow duty cycles within an ambient temperature range of 20° to 100°F. This temperature range corresponds to a saturation pressure range of 48.2 to 212 psia. The operating modes included continuous flow at rates of 3×10^{-5} to 1×10^{-3} lb/sec and pulse flow at duty cycles in the range of 1 to 3 percent with ON-times in the range of 50 to 300 milliseconds. The flow rate during a pulse was in the range of 5×10^{-4} to 1×10^{-3} lb/sec. Liquid and vapor phase ammonia was extracted from the storage tank during these tests. The vapor pressure of the ammonia was sufficient to drive the system so that no external pressurization was required. The system demonstrated the capability of maintaining a pressure control band of $\pm$ 1.0 psi around the nominal over a large range of ambient temperatures and duty cycles and with either vapor or liquid exhaust from the storage tank. During all required test conditions, only vapor phase ammonia was discharged from the capillary tubes.

The results of the one-month demonstration test indicate that it is possible to assemble an ammonia propellant feed system that is similar in design simplicity, in operational stability, and in regulation characteristics to those of high pressure gas systems. In addition, the demonstration system verified the weight advantage of ammonia over high pressure gas. The ammonia demonstration system dry weight was 8.5 pounds for an actual total stored ambient impulse of 3380 pound-seconds. The total system weight with propellant was 42.3 pounds.

2. SYSTEM DESIGN

The ammonia propellant system designed for this program includes a propellant storage tank, a two-phase flow pressure regulator, and a capillary tube heat exchanger. It is designed to operate in the zero gravity environment of space and supply vapor phase ammonia propellant within a controlled pressure band. Liquid phase ammonia is stored in the propellant tank. The tank volume not occupied by liquid contains saturated ammonia vapor. The pressure regulator controls the delivery pressure of the propellant and the propellant flow from the storage tank. In a zero gravity environment, location of the vapor-liquid interface within the storage tank is not predictable; therefore, either liquid or vapor phase ammonia or both can be exhausted from the storage tank. Thus, in order to control propellant flow, the pressure regulator must be able to operate on either liquid or vapor phase ammonia. When vapor phase ammonia is leaving the storage tank, the vaporization process occurs at the vapor-liquid interface within the tank. As the vapor is expanded from the storage tank pressure to the delivery pressure, there is no phase change; therefore, no propellant conditioning is required. When liquid phase ammonia is leaving the storage tank, a means must be provided to accomplish the vaporization. A net flow of thermal energy into the liquid phase ammonia is required to achieve the phase change. The capillary tube heat exchanger is incorporated in the propellant system to provide this heat transfer and phase change function.

2.1 System Requirements

In order to determine the design characteristics of the propellant system components, it is necessary to establish system requirements. These requirements include:

- Total propellant
- Operating temperature range
- Propellant flow rate
- Propellant duty cycles
- Propellant delivery pressure

The basic requirements selected for the system were based on typical spacecraft missions. However, analyses, performed to establish system characteristics, indicated operational limitations which are discussed in Section 2.2.

2.1.1 Original System Requirements

A list of the critical operating requirements for the ammonia propellant system is presented in Table 1. These requirements were established on the basis of the environmental and operational conditions encountered on a wide range of spacecraft and missions. Results obtained in the system thermal analysis indicated that the system was unable to maintain high propellant flow rates without the addition of internal tank fins and/or a heat source. Because of this, the system critical operating requirements were modified.

TABLE 1.

CRITICAL SYSTEM OPERATING CRITERIA

I.	Propellant Storage Mass:		50 pounds
II.	Operating Temperature Range -	Spacecraft Interior:	20 - 100°F
		Spacecraft Exterior:	0 - 120°F
III.	Maximum Flow Range-	Average:	4×10^{-4} lb/sec
		Instantaneous:	10^{-3} lb/sec
IV.	Temperature Range During Maximum Flow:		50 - 100°F
V.	Duty Cycle History -	Acquisition:	full propellant tank
		Station-keeping:	>5% residual propellant
		Station-changing:	>25% residual propellant
		Attitude Control:	continuous
VI.	Allowable Pressure Variation:		±10 percent
VII.	Mechanical Environment -	Vibration, etc:	Titan III C
		Safety factor:	burst pressure-2.2
VIII.	Telemetry and Command:		activation
			isolation
			diagnosis

2.1.2 Modified System Requirements

A list of the modified system critical operating requirements is presented in Table II. These requirements are more explicit with respect to propellant duty cycles and flow duration. The tank size was decreased to reduce cost and improve component delivery schedule.

TABLE 2.

MODIFIED SYSTEM CRITICAL OPERATING CRITERIA

I.	Propellant Storage Mass:		36 pounds
II.	Operating Temperature Range:		20 - 100°F
III.	Flow Rate -	Maximum (300 seconds):	10^{-3} lb/sec
		Instantaneous:	10^{-3} lb/sec
		Continuous:	3×10^{-5} lb/sec
IV.	Temperature Range -		
		Maximum Flow:	40 - 100°F
		Continuous Flow:	25 - 100°F
V.	Duty Cycle History -	Maximum Flow:	Full propellant tank
		Continuous Flow:	>5% residual propellant
		Pulsed Flow:	100% to 0 residual propellant
VI.	Allowable Pressure Variation:		±10 percent
VII.	Mechanical Environment -	Vibration, etc.:	Titan IIIC
		Safety factor:	Burst pressure - 2.2
IX.	Telemetry and Command:		Activation Isolation Diagnosis

2.2 SYSTEM THERMAL ANALYSIS

Thermal analyses were performed on the system to determine the time-temperature history of the stored propellant under various flow demands and with various quantities of stored propellant. The influence of thermal radiation from an external heat source was also examined. The purpose of these analyses was to determine the range of propellant flow duty cycles that could be maintained by the propellant system. The propellant storage tank surface temperature history at high propellant flow demand was also determined. This information is required, in conjunction with the capillary tube analysis, to determine maximum allowable duty cycles and flow on times when liquid phase ammonia is leaving the storage tank.

2.2.1 High Propellant Demand

For the original system requirements, the high propellant flow demand was defined as a flow rate, $\dot{m}$, of 4×10^{-4} lb/sec. This flow demand would be required for periods in excess of 6 hours for station changing maneuvers. The thermal energy required to maintain this flow rate is approximately 226 watts. The first analysis was performed to determine the average stored propellant temperature during flow with no heat addition. The analytical expression describing this case is:

$$-M\ C_p\ \frac{dT}{d\theta} = q_v \qquad (1)$$

where M = mass of propellant in the storage tank

C_p = specific heat of the propellant

T = temperature

θ = time

$q_v = \dot{m}\ h_v$ = heat to vaporize propellant

$\dot{m}$ = propellant mass flow rate

h_v = propellant heat of vaporization

Solutions to equation (1) for several values of propellant mass in the storage tank are shown in Figure 1. The initial propellant charge in the tank, $M_o = 1$, was assumed to be 50 pounds and the thermal properties of the ammonia used in the analysis were averaged over the temperature range of 0° to 100°F.

A second analysis considered the presence of an external radiation heat source. The analytical expression describing this case is

$$-M\ C_p \frac{dT}{d\theta} + q_r = q_v \qquad (2)$$

where

q_r = radiative heat input to the storage vessel

$q_r = \sigma FA(T_s^4 - T^4)$

σ = Boltzman constant

F = Gray body radiation factor

A = surface area of storage vessel

T_s = temperature of the surroundings

T = temperature of the storage vessel

Solutions to equation (2) for several values of propellant mass in the storage vessel and for an initial temperature of 50°F are shown in Figure 2. The assumptions used in the solution to equation (2) were:

(1) The temperature of the surroundings is constant with time and equal to the initial storage vessel temperature.

(2) The storage vessel is a 17 inch diameter sphere. (50 pounds of ammonia)

(3) The area ratio between the storage vessel and the surroundings is unity.

(4) The thermal emissivity of all surfaces is equal to 0.85.

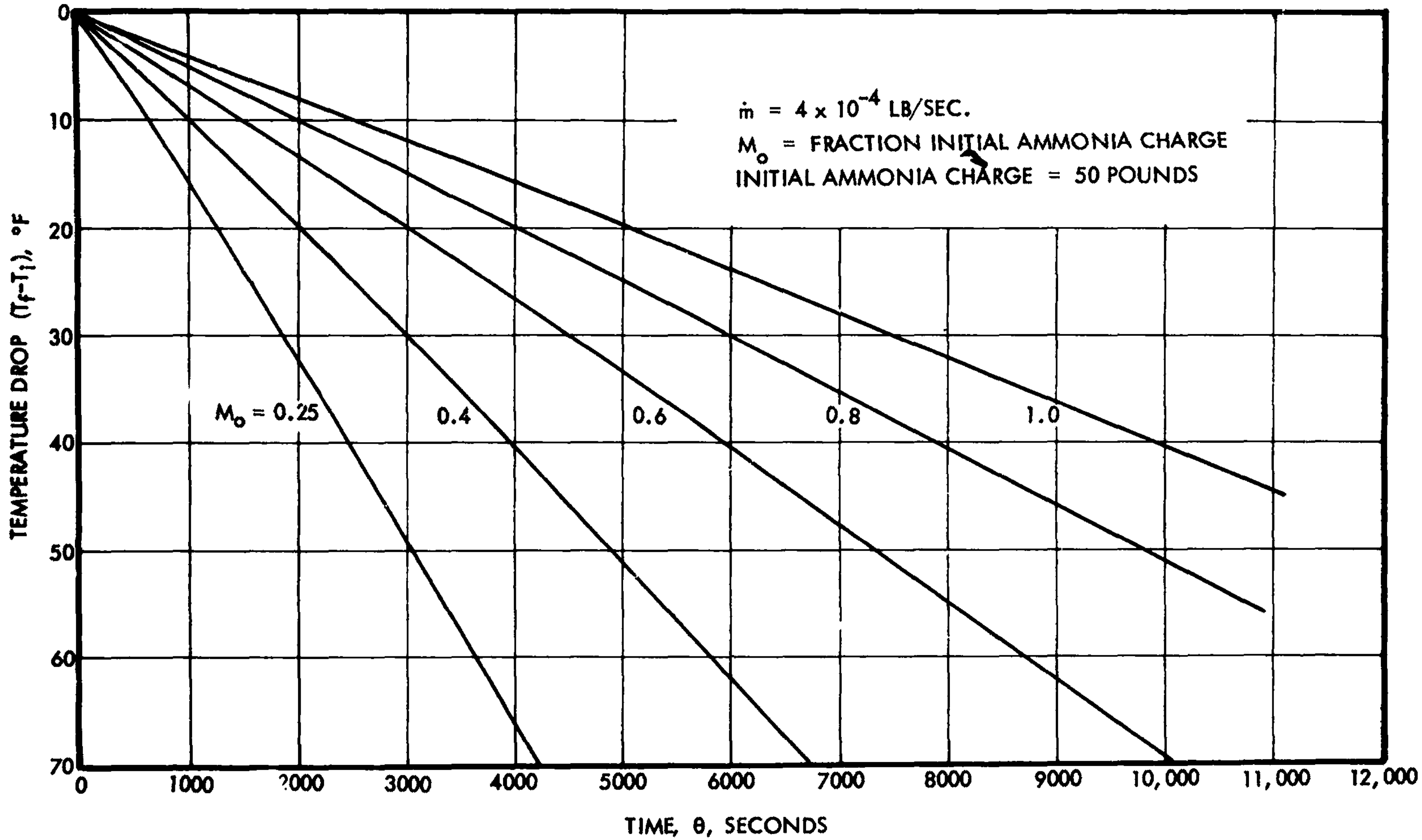


Figure 1. Propellant Average Temperature History, No Heat Input

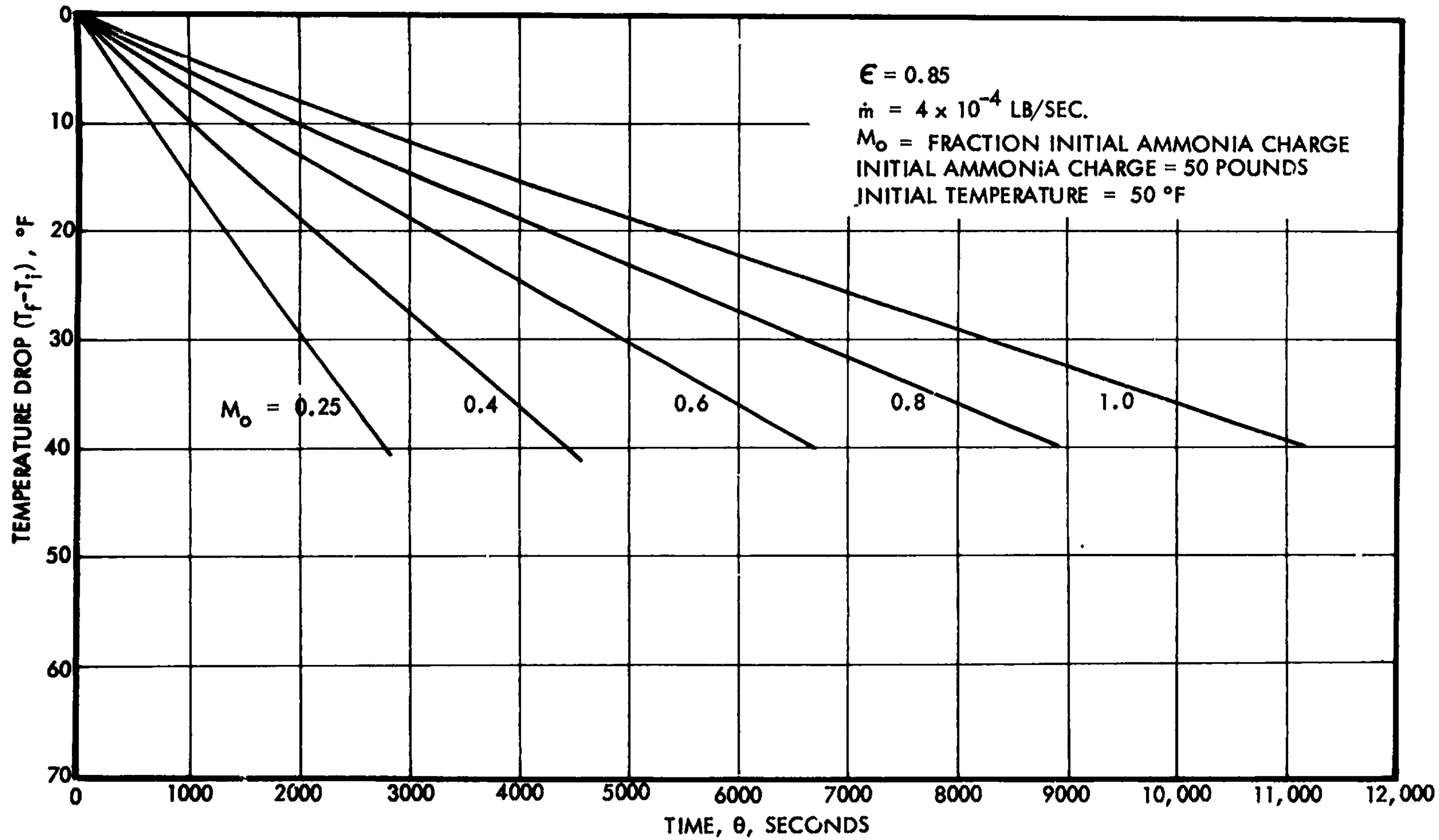


Figure 2. Propellant Average Temperature History, Radiative Heat Input

The results of the analyses of these two cases indicate that the duration of maximum propellant flow can be limited to several hours or less when only the stored thermal energy of the propellant is available for vaporization or when thermal radiation from the surroundings is the only additional heat source. An even more severe restriction to flow times occurs because of nonuniform temperature distribution within the propellant. This will be most pronounced when liquid phase ammonia is leaving the storage tank. In this case, when the vaporizer is attached to the tank wall, the propellant next to the tank wall will drop in temperature at a considerably faster rate than the average propellant temperature. This places an additional limitation on the stored thermal energy available to vaporize the ammonia propellant. To circumvent these limitations, an external heat source, such as a heater element and/or internal tank fins must be incorporated in the system.

For the modified system requirements, the maximum flow demand is 10^{-3} lb/sec, which is higher than the original requirements; however, the required flow time is only 300 seconds. The thermal energy required to maintain this flow rate is 565 watts. The propellant storage tank has a capacity of 36 pounds. Solution to equation (1) at a full tank loading indicates that the average propellant temperature will decay at a rate of 1°F per minute or a total of 5°F over the 300 second flow period. These temperature values will be proportionally higher with less ammonia in the tank; however, this maximum flow will occur when the tank is at or near full capacity. The minimum start temperature of the maximum flow rate is 40°F. This temperature corresponds to a saturated ammonia pressure of 73.3 psia. After the 300 second flow period in which the average temperature drops 5°F, the saturated ammonia pressure is 66.3 psia. This pressure decay will not present a problem in the system's ability to maintain the delivery pressure at the flow rate.

The basic limitation in determining the duration that the system can maintain the maximum flow rate is related to nonuniform temperature distribution in the propellant. When liquid phase propellant is leaving the storage tank, it is vaporized in the capillary tube vaporizer which is in thermal contact with the outer surface of the propellant tank. The tank wall, therefore, serves as a heat transfer fin for extracting thermal energy from the stored propellant. The limiting case for extracting heat from the propellant is when liquid phase in in contact with the tank wall. Under this condition, the absence of convection in the zero gravity environment restricts total heat extraction from the propellant to conduction. The time limit for the flow period will be determined by the tank surface temperature history during the flow period. The temperature history of the tank surface can be determined by solving the heat conduction equation

$$\nabla^2 T = \frac{1}{\alpha} \frac{\partial T}{\partial \theta} \tag{3}$$

∇ = Laplacian operator

$T = t - t_i$

t = temperature

t_i = initial temperature

θ = time

α = thermal diffusivity

If the propellant layer through which a major portion of the temperature change occurs is thin, a reasonable approximation to the storage tank case can be made by assuming slab geometry. Solution of equation (3) in slab geometry with the boundary condition that the heat flux is independent of time is

$$T = \left(\frac{q\sqrt{\alpha}}{k}\right) \left[2\sqrt{\frac{\theta}{\pi}} \; \exp\left(\frac{-x^2}{4\alpha\theta}\right) - \frac{x}{\alpha^{1/2}} \operatorname{erfc}\left(\frac{x}{2\sqrt{\alpha\theta}}\right)\right] \tag{4}$$

where

q = heat flux per unit area

x = distance in from the tank surface

k = thermal conductivity

At the tank surface, equation (4) reduces to

$$\frac{2q}{k}\sqrt{\frac{2\theta}{\pi}} \tag{5}$$

A solution to equation (5) corrected for tank wall contribution and using the nominal system parameters is shown in Figure 3. The propellant tank size, shape and weight for which the solution is based are described in

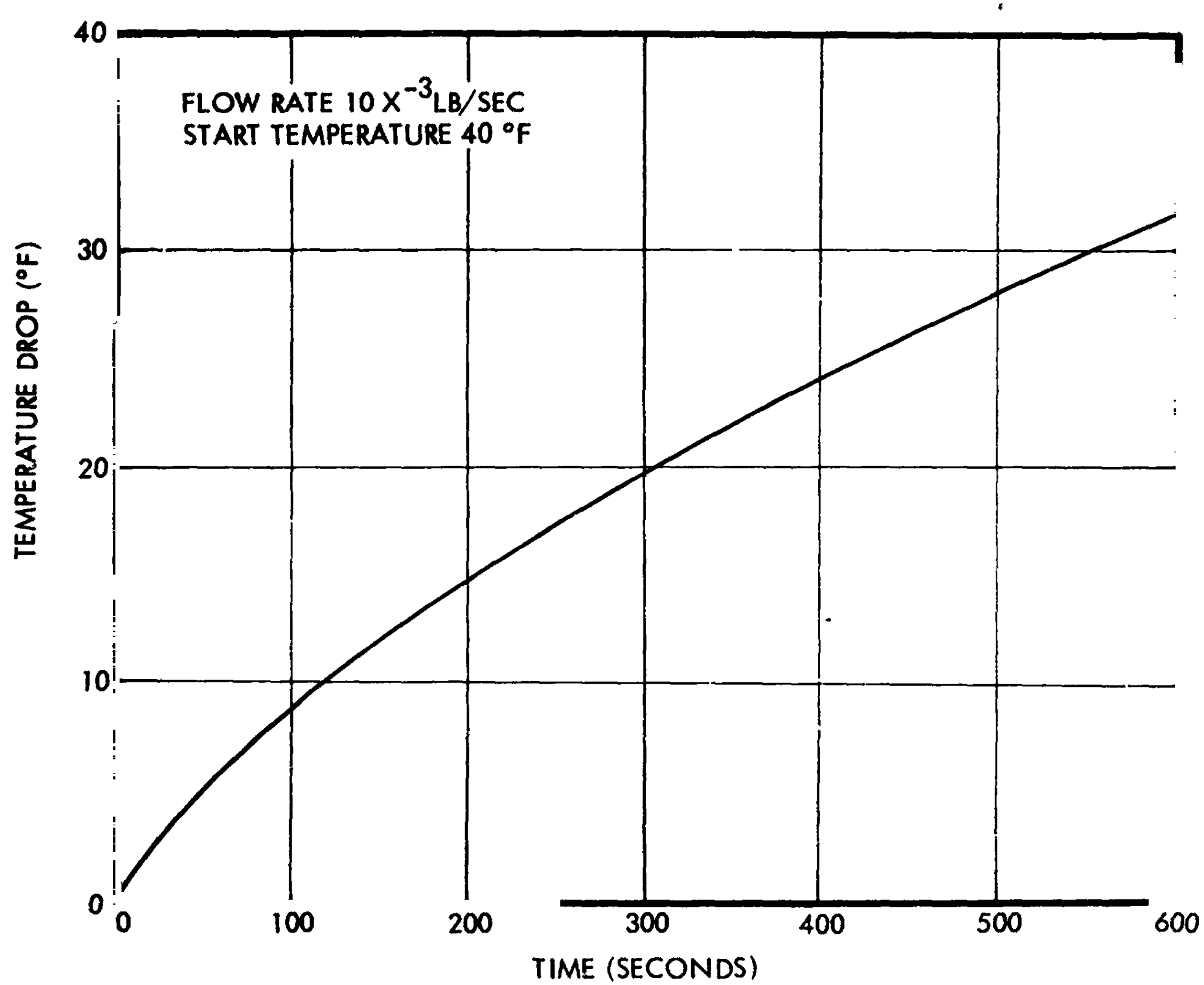


Figure 3. Storage Tank Wall Temperature

Section 5.2. The maximum temperature potential $(t - t_i)$ available for the high flow demand maneuver is the difference between the propellant temperature at the start of the flow and the propellant saturation temperature at the delivered pressure. However, not all of this temperature potential is available as allowable wall temperature decay during flow. A portion of the temperature difference is required for transferring thermal energy from the capillary tube walls to the propellant flowing in the tubes. This temperature drop analysis and flow duration limits are in Section 4.1.

2.2.2 Low Propellant Demand

The low flow demand requirement includes flow rates equal to or less than 3×10^{-5} lb/sec. These flow rates can be maintained continuously if sufficient heat (~17 watts) is transferred to the propellant tank from the surroundings. Equation (2), with the following assumptions, describes this condition.

(1) Temperature of the surroundings is constant with time and equal to the initial storage vessel temperature.

(2) The storage vessel has the dimensions described in Section 5.2.

(3) The area ratio between the storage vessel and the surroundings is unity.

(4) The thermal emissivity of all surfaces is equal to 0.85.

Under these conditions, with a starting temperature of 25°F, (minimum temperture requirement), the equilibrium tank wall temperature will be 3°F. This equilibrium temperature will be independent of the ammonia phase leaving the tank. When the tank is filled with propellant, the time required to reach equilibrium is approximately 60 hours. With less than full propellant loadings, the time will be proportionally shorter. At the temperature differential of 22°F, all of the energy required for vaporization is supplied by radiation to the tank. If the temperature at initiation of flow is above 25°F, the equilibrium temperature will be less than 22°F below the starting temperature. The tank pressure at the minimum temperature of 3°F is 32.7 psia. This pressure is sufficient to maintain the propellant flow rate (3×10^{-5} lb/sec) at a delivery pressure of 20 psia.

3. REGULATOR DESIGN

Control of the ammonia feed system pressure downstream of the capillary tube heat exchanger requires a unique pressure regulator. High response control of either liquid or gaseous ammonia flowing into the capillaries must be achieved. A high order of shutoff reliability must also be attained since no other shutoff provisions are included in the feed system. The regulators developed in this program are specialized in design to meet these basic requirements.

A single stage, spring loaded, diaphragm regulator design was chosen to meet the program requirements. A complete set of drawings of the final regulator design is in Appendix I. The design emphasizes ease of assembly and adjustment. An elastomer valve poppet seal was used to provide a simple, highly reliable, sealing capability. The seal also offers a high tolerance to particle contamination and good wear characteristics. The valving and sensing arrangement adopted in the regulator design was dictated by the need for minimum volume at the capillary inlet and the requirement for remote sensing.

3.1 PROTOTYPE REGULATOR

3.1.1 Prototype Regulator Requirements

The general requirements for the regulator were established by the physical and functional characteristics of the system, coupled with developmental needs. Highly reliable shutoff of the capillary tube inlet with a minimum of residual volume was required. Remote pressure sensing was demanded by the basic system functions. Materials compatibility with gaseous and liquid ammonia was necessary. Characteristics established for the prototype regulator were:

- Adjustability over a regulated pressure range
- Assembly characteristics allowing for easy assembly and disassembly for replacement of sensing diaphragms, valve poppets and seats as necessary for component and system development.
- Minimum weight and envelope consistent with ease of assembly and other desirable characteristics directed to a non-flight development unit.

The specific design requirements were:

a) Pressures

Pressures	Valve	Diaphragm
Working pressure, psig	210 max	37 max
Proof pressure, psig	315	55
Burst pressure, psig	462 min	87 min

Regulated pressure

Adjustable from 20 to 35 psig

Regulation accuracy within ±5% over inlet pressure and flow range

Lockup pressure

Within regulation accuracy, 0.6 psi maximum above calibrated regulation pressure

b) Flow

Maximum flow: 1×10^{-3} lb/sec of ammonia at a minimum inlet pressure of 66 psia.

Minimum flow: 3×10^{-5} lb/sec ammonia at a minimum inlet pressure of 54 psia.

c) Temperature

20 to 100°F

d) Leakage

External: 2×10^{-5} scc/sec GHe total

Internal: 0.3 scc/hr GN_2

3.1.2 Prototype Regulator Design

A cross-sectional view of the regulator is shown in Figure 4. Photographs of the assembled unit and the disassembled components are shown in Figures 5 through 7. The relationship of the regulator to the feed system is described in Section 5.0, Prototype Feed System, and is shown schematically in Figure 27.

Ammonia from the supply tank is introduced directly to the metering valve, which consists of the elastomer seat poppet and a stationary metal seat. The ammonia flow enters the capillary tube assembly downstream of the seat orifice.

One of the ports to the diaphragm sensing chamber is connected to the downstream side of the capillary tubes. The other port was provided to

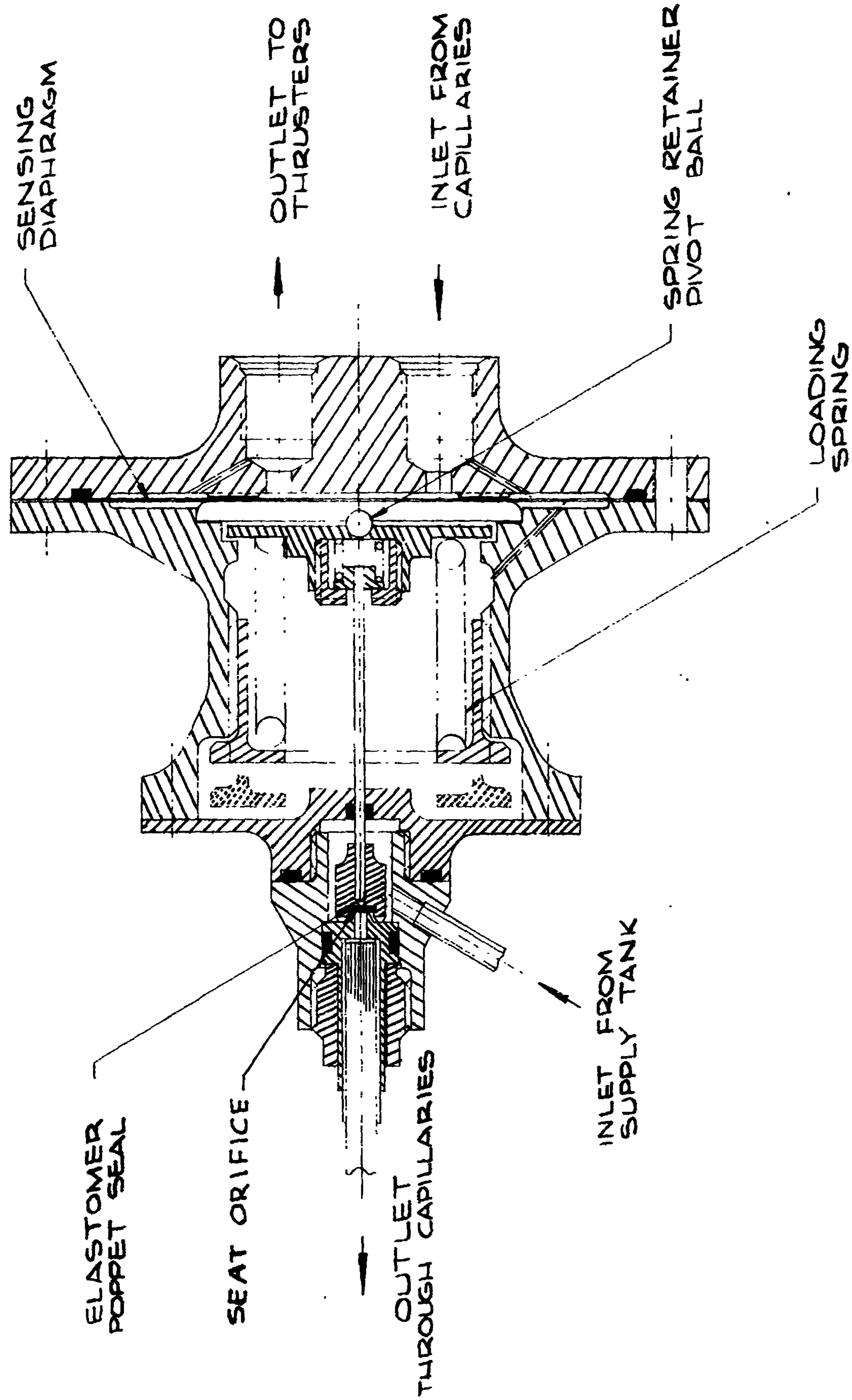


Figure 4. Prototype Regulator Cross Section

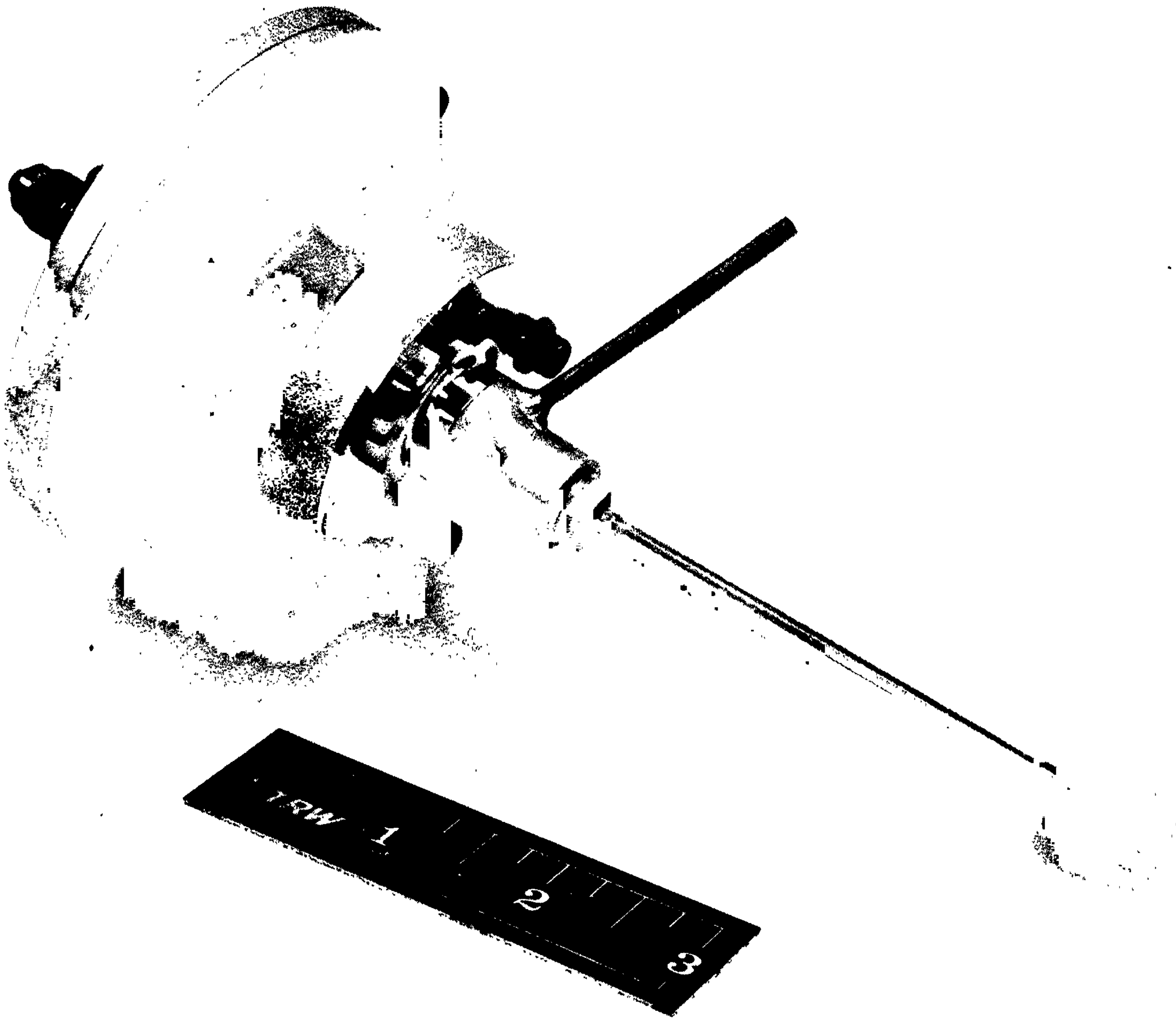


Figure 5. Regulator Assembly

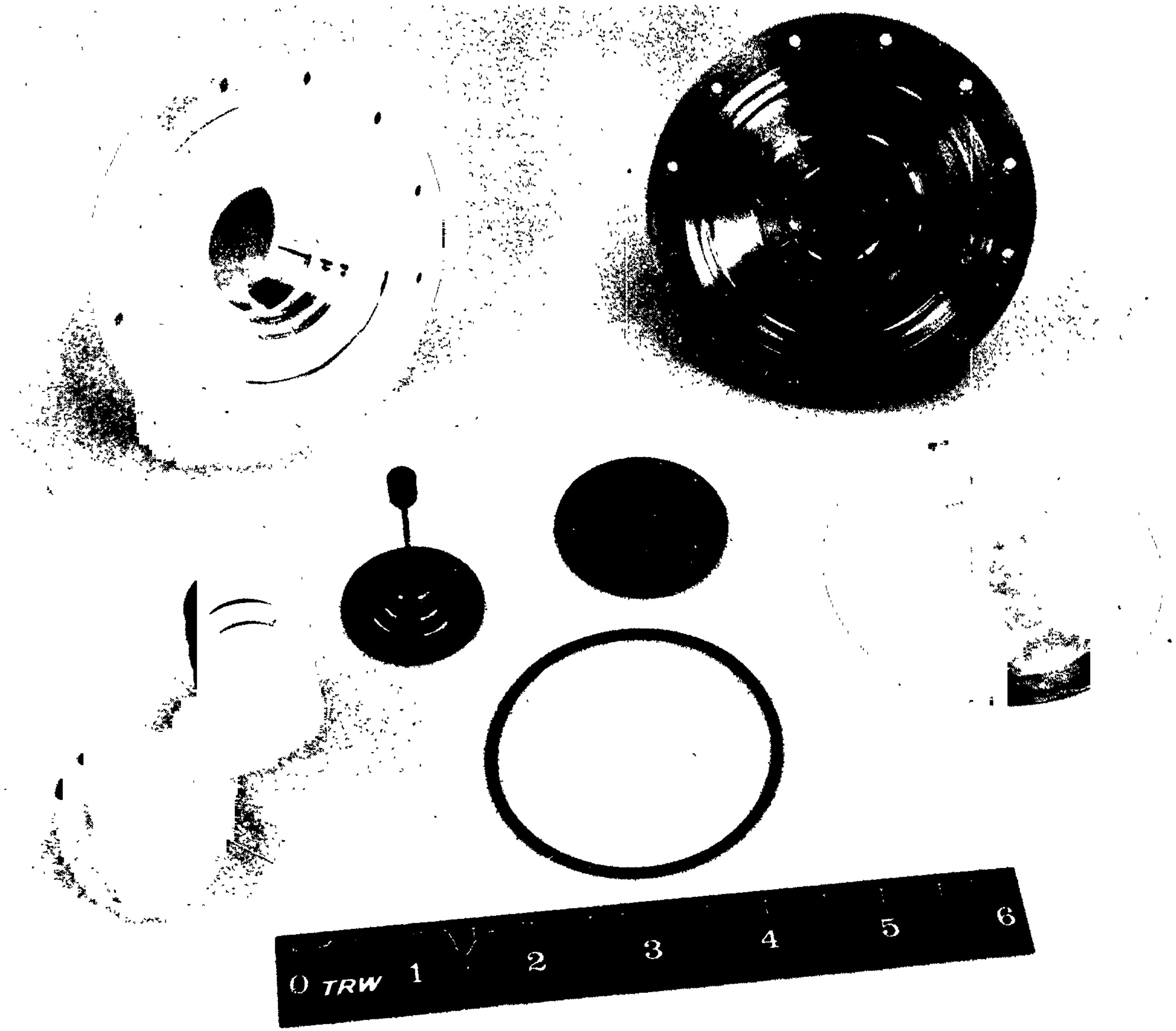


Figure 6. Diaphragm Components

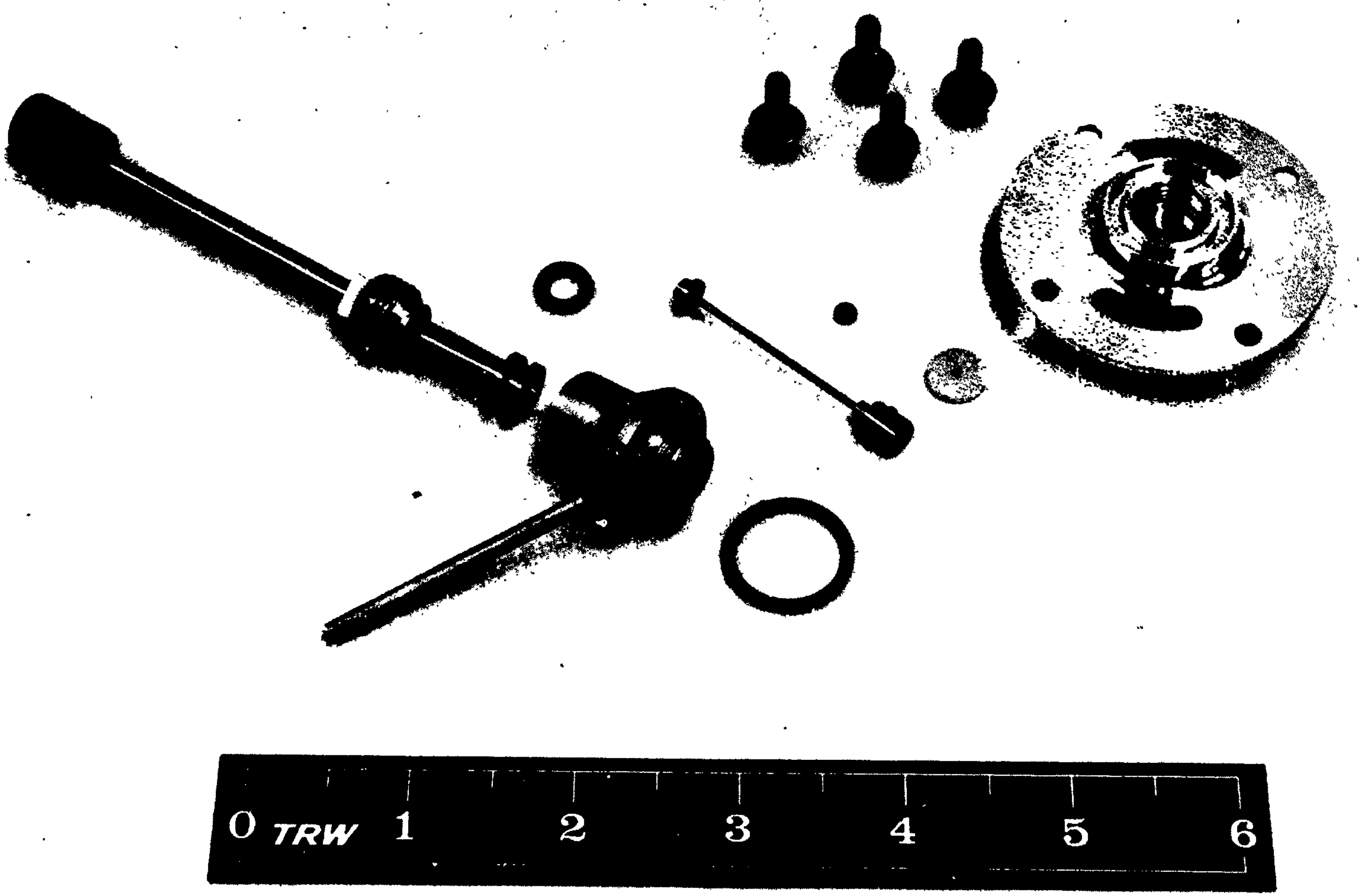


Figure 7. Poppet Components

to allow the option of either flowing from the capillary tubes into the diaphragm sensing chamber through one port and out the other, or dead-ending a sensing line at one port and connecting a pressure sensor at the other.

Whenever the feed system pressure (sensed pressure) is lower than the calibration pressure of the regulator, the regulator metering valve opens and ammonia is free to flow into the capillary tubes. As the calibrated pressure is reached and sensed by the diaphragm, the valve meters the flow. If the flow demand to the regulator is stopped, the metering valve closes and the regulator is at lockup. The downstream system pressure at this condition is limited to 0.6 psi maximum above the normal metered calibration pressure.

The design arrangement makes possible independent installation of the diaphragm with the loading spring and valve parts of the unit. This is illustrated in Figures 6 and 7. The parts constituting the diaphragm assembly are shown in Figure 6, and the valve assembly in Figure 7. During regulator assembly, the diaphragm portion (including the loading spring and the valve shaft) is assembled first. The valve and plate, held by four screws, are mounted on the regulator body. The shaft "O" ring and backup disk are then installed. The poppet is mounted on the shaft and locked in place by a set screw. The remaining parts and seals are inserted to complete the assembly.

The prototype regulator design includes an over-travel spring device at the connection of the valve shaft and the loading spring plate. This allows the poppet to bottom on the seat before the diaphragm back plate bottoms in the regulator housing, and avoids overloading the valve shaft if a pressure above the normal regulated value is sensed by the diaphragm. The ball between the spring retainer and the backing plate provides for self-alignment of the loading spring independent of the diaphragm. The ball also provides a low friction pivot allowing rotation of the loading spring without imposing torque on the diaphragm when calibration adjustments are made. Self-alignment of the valve shaft is also provided with the spherical surface of the over-travel device centered at the pivot ball center.

The diaphragm is a center-supported flat membrane design. The unsupported working area has an outside diameter of 2-1/2 inches and an inside diameter of 1-1/2 inches. A slight annular disk is formed in the working annulus by preloading to 80 psig. The membrane is manufactured from 0.003 inch annealed 302 stainless steel sheet.

The regulated pressure adjustment is made with a spanner wrench inserted through slots in the valve end-plate, and engaging the notches in the adjustment nut. The nut is rotated a notch at a time until the desired position is reached.

Pertinent design features of the regulator are:

Seat orifice diameter	0.062 inch
Poppet stroke	0.020 inch
Diaphragm stroke	0.025 inch
Poppet shaft diameter	0.050 inch
Diaphragm effective diameter	2.0 inch
Diaphragm effective area	3.14 $inch^2$
Loading spring force at maximum design regulated pressure (35 psid)	110 pounds
Overtravel spring force	2.6 pounds

Except for the seals and the spring, aluminum and stainless steel are used throughout the design. All the major exterior parts are made of 6061-T6 aluminum alloy. The seat, poppet and poppet shaft, the spring plate and diaphragm plate are made of 303 stainless steel alloy. Both springs are a high grade spring steel, stress relieved and preset. The "O" ring seals consist of EPR rubber (Parker compound E515-8). The poppet seal, made of butyl rubber (Stillman Rubber compound SR 634-70), is molded in place and bonded.

The weight of the prototype regulator is 0.92 pounds.

3.1.3 Prototype Regulator Test

3.1.3.1 Development Tests

The development tests of the prototype regulator were conducted to optimize and verify the basic function of the diaphragm assembly, loading springs, and the valve poppet seal. The test plan for these tests is included in Appendix II of this report.

Initial tests were run to establish an optimum diaphragm material and thickness. After working with samples of both stainless steel and aluminum, it was determined that stainless steel was the more practical choice from the standpoint of handling, serviceability and material uniformity. A 0.003-inch thick annealed sheet of 302 stainless steel ultimately proved to provide a good balance of flexibility and pressure strength. The operating characteristics of the combined loading spring and diaphragm are shown in Figure 8. The motion of the diaphragm was measured at a series of pressure increments with the loading spring set arbitrarily to obtain motion between 20 and 25 psig. Nonlinearity is less than 2% between 0 and 0.020 inch of motion. The pressure versus deflection rate is approximately 0.26 psi per 0.001-inch motion. Hysteresis for the assembly was not measurable and must be assumed to be less than 0.002 inch. Once deformed at 80 psig, no change in diaphragm dimensions was measured with repressurization to the proof pressure of 55 psig.

Preliminary tests were conducted to determine the poppet valve functional characteristics. Operating forces under all conditions were observed to be less than one pound, accounting for both friction and pressure at 210 psig. Nitrogen leakage at 210 psig was not measurable over a one-hour period.

Following the subcomponent tests, the regulator assembly was completed. Regulator performance was evaluated with the unit installed in a test setup per Figure 79 of Appendix II. The adjustable regulated pressure range of 20 to 35 psig was found to be within the loading spring adjustment range. A series of tests was conducted to observe the effect of inlet pressure variation on regulation. Data at settings of 20 to 30 psig are shown in Figure 9. At a minimum inlet pressure of 50 psig, a pressure excursion of approximately 1 psi is observable for both the 20 and 30 psig settings over the design flow range of 3×10^{-5} to 1×10^{3} ammonia (2 SCFH to 68 SCFH of GN_2). Further evaluation of the capillary restriction between the valving and sensing functions of the regulator was considered necessary to evaluate the significance of these data during system operation. In view of the overall regulation band objective of $\pm 10\%$ for the system, the regulator pressure excursion appeared to be acceptable and testing was continued.

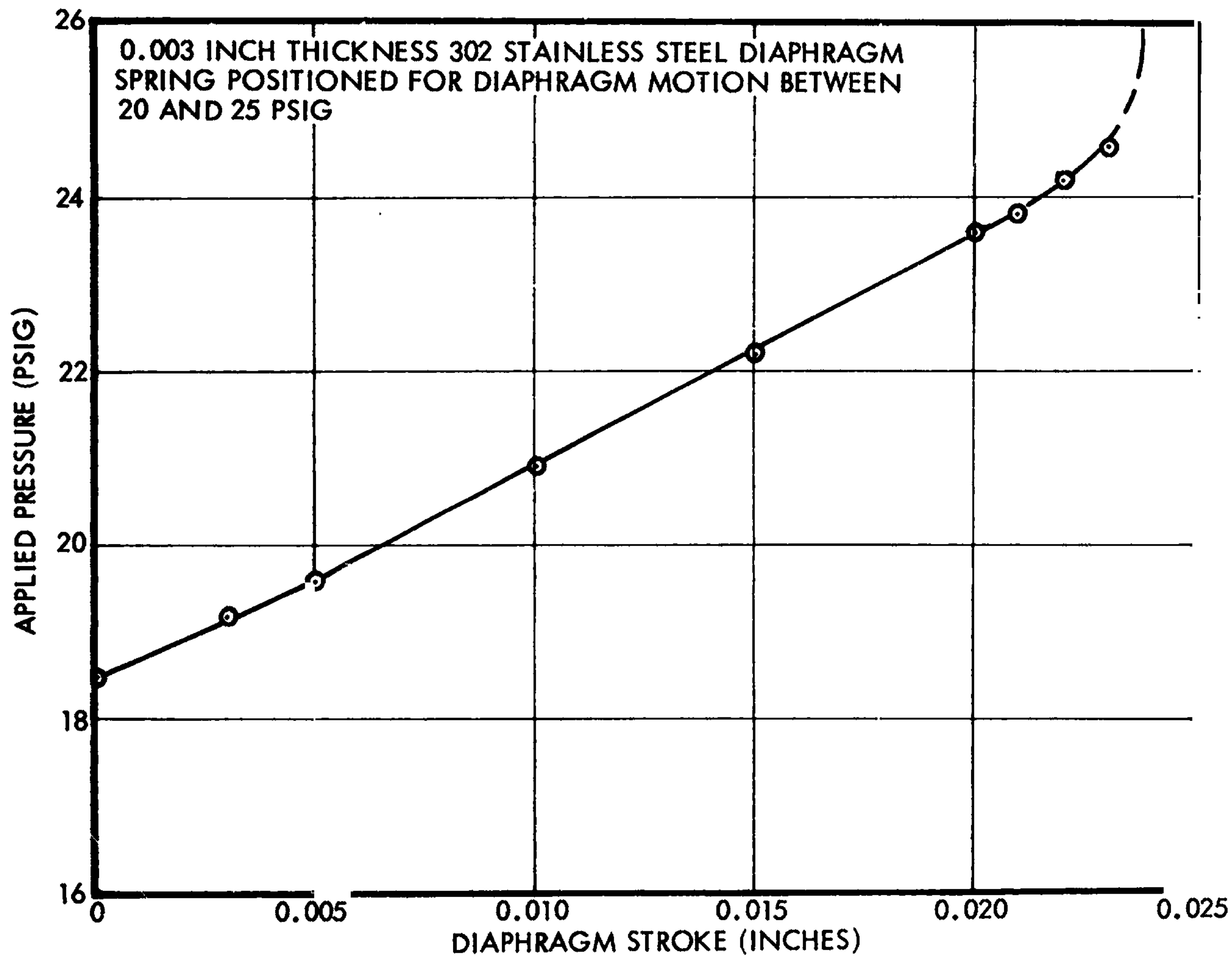


Figure 8. Diaphragm Deflection

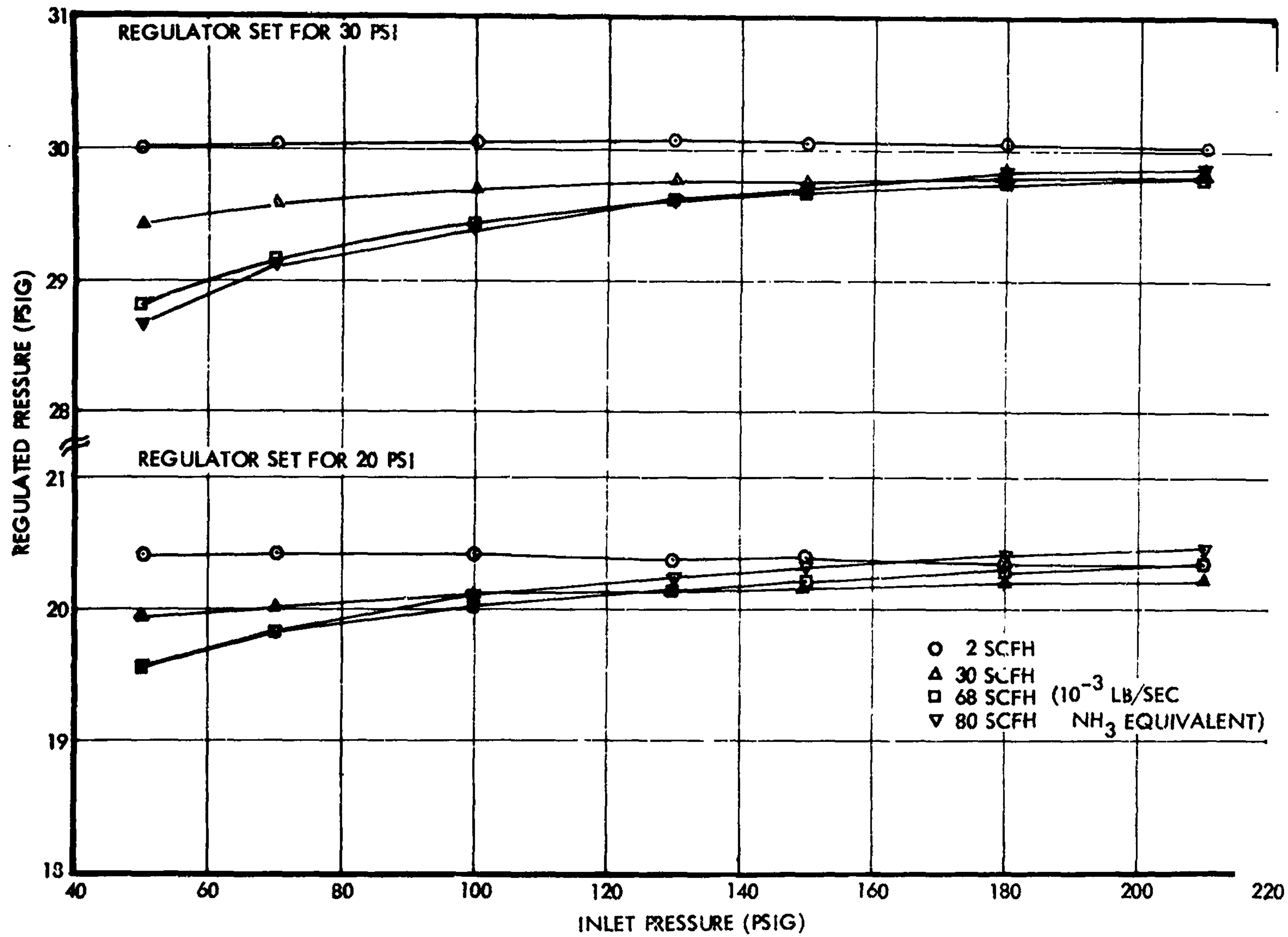


Figure 9. Ammonia Regulator Control Characteristics, Gaseous Nitrogen Flow

The effect of throttling the capillary tube simulation valve indicated the regulator function to be stable. Low frequency oscillations of the order of 0.2 Hz could be detected when the valve was nearly closed, the inlet pressure near minimum, and flow near minimum. Inasmuch as the conditions were extreme and the characteristic not inherent in the regulator, further evaluation could only be made on the actual system. No instabilities could be triggered by sudden shutoff. Lockup pressure at maximum flow in the referenced system was found to be approximately 0.20 psi above the regulated pressure.

Pressure drop tests of the regulator were run to establish the basic characteristic with the valve full open. The data are shown in Figure 10. The pressure drop through the prototype regulator was 3.7 psi at a 66 psia inlet pressure and a flow of 68 SCFH.

3.1.3.2 Materials Compatibility Test with Ammonia

The compatibility of the poppet seal and seal bond with liquid and gaseous ammonia was tested by exposing two spare valve poppets to an ammonia environment. These initial test seals were molded of an EPR rubber (designated TRW 8396-54-1). After a 72-hour exposure, the seals appeared unchanged. To assure that the exposure had not affected the seals, one of the exposed seals was installed in the regulator in place of the one previously tested with nitrogen. It was found that the bond had failed and the seal moved under pressure.

At this point Stillman Rubber Company was contacted to obtain a proven bonding technique. A proprietary butyl compound (SCR 634-70) was recommended. A repeated 72-hour preliminary exposure of butyl seals to liquid ammonia indicated good bond quality. Again, one of the exposed seals was installed in the regulator. No bonding failures were experienced during subsequent testing.

3.1.3.3 Acceptance Tests

The acceptance test plan is included in Appendix II. The acceptance test procedure for the ammonia feed system pressure regulator, including the test results for the prototype unit, is presented in Appendix III. The regulated pressure (at minimum flow) of the prototype regulator was

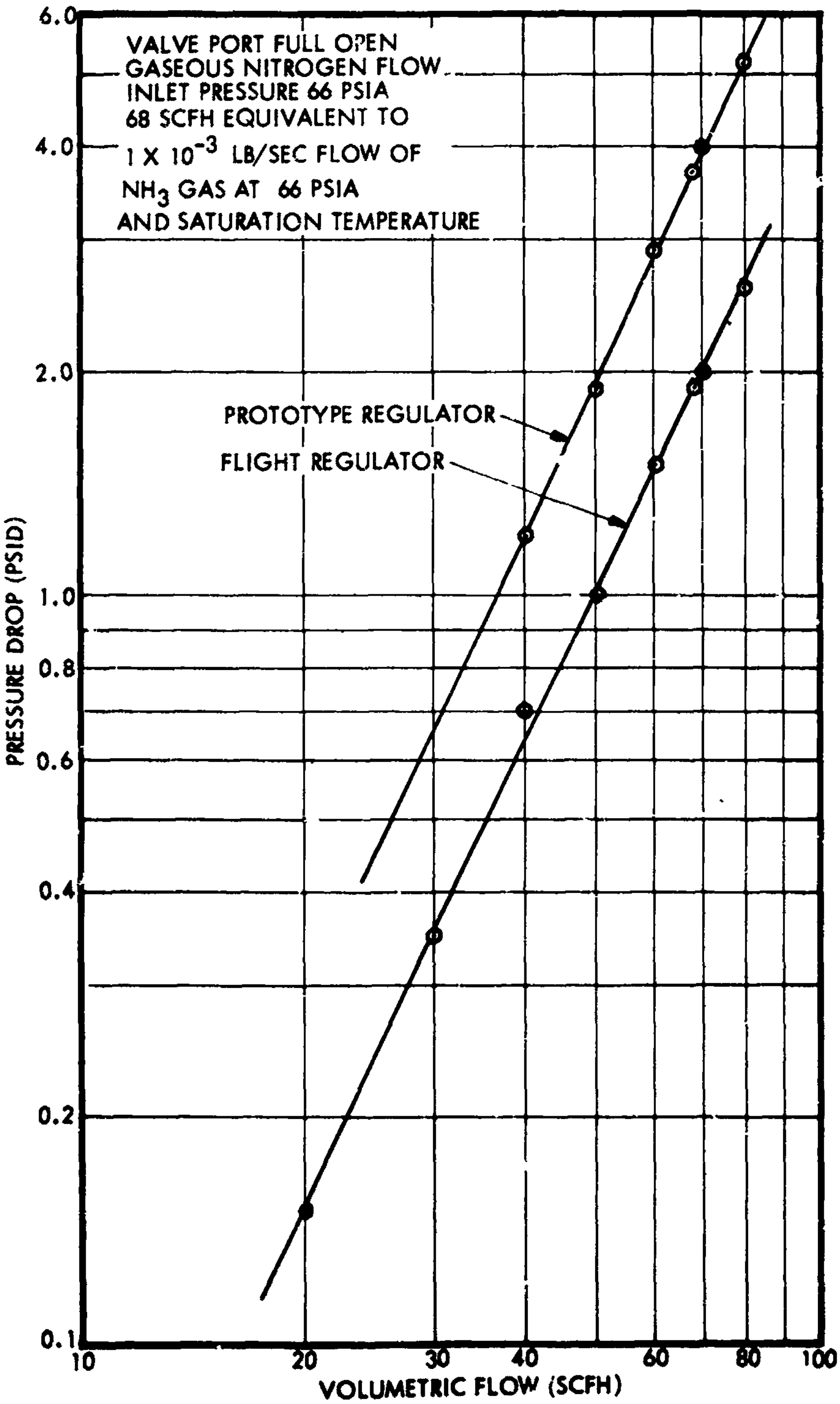


Figure 10. Ammonia Regulator Pressure Drop

set at 20.05 psig. Maximum observed lockup pressure was 20.4 psig. Internal leak rate with GN_2 at maximum inlet pressure was measured at 0 scc/hr.

After completing the acceptance test, the unit was installed in the prototype feed system.

3.1.3.4 Ammonia Test Evaluation

Discussion of the prototype regulator performance with ammonia is covered in detail under Section 5.3 as part of the feed system performance. The pressure drop between the supply tank and the capillary tube inlet was found to be greater than expected; however, this was improved to some extent by reducing the pressure drop in connecting lines and in the supply line filter. Ammonia pressure drop tests of the regulator at varying valve positions indicated an increase of valve seat orifice size would be desirable for the flight configuration.

An oscillating characteristic of pressure regulation was observed with liquid flow tests of the system. This function was not unexpected due to the inherent lags between the regulator valve opening or closing and the resulting pressure increase or decrease in the downstream system. The regulator response characteristic ($\sim$100 Hz) is much higher than the one-half to one Hz characteristic observed with the system. Because the amplitude of the oscillations was well within the desired pressure regulation band, the only concern with regard to the regulator would be the seal life requirements for a given mission.

Following the ammonia tests, the regulator was functionally retested and then disassembled and the parts inspected. No corrosion or wear was evident in the area of the shaft seal and guide bearing. However, all of the "O" ring seals had a tackiness when the unit was first disassembled. The characteristic disappeared after several hours with no apparent damage to the elastomer. The phenomenon appears to be attributable to the ammonia that had permeated into the rubber and had subsequently reacted with moisture in the air to produce a hydroxide on the "O" ring surface.

Recheck of the pressure calibration following the ammonia tests indicated a lock-up pressure of 19.95 psid, which was 0.1 psi lower than at the start of the test.

3.2 FLIGHT-TYPE REGULATOR

3.2.1 Flight-Type Regulator Requirements

The specification requirements for the flight regulator were unchanged from the prototype except as noted below. The primary change in design approach was to emphasize reduction in weight and to select assembly methods more suitable to flight qualification. The following design features were chosen for the flight type regulator design:

1. The pressure adjustment range of the regulator remained within 20 to 35 psig.
2. The inlet tube connection was increased to a 3/16-inch diameter tube size from the 1/8-inch used in the prototype.
3. The prototype bolted diaphragm assembly was retained.
4. Provision was made for evacuation of the ambient reference side of the diaphragm.
5. A tube header was designed for attachment of the capillary bundle to the regulator.
6. A means for structural mounting the regulator to the ammonia tank was provided.
7. The weight of the regulator was reduced where possible, within cost and schedule constraints of the program.

3.2.2 Flight-Type Regulator Design

The flight-type regulator design is functionally identical to the prototype model. Minor design changes were incorporated to meet the requirements of Section 3.2.1. The regulated pressure adjustment range was maintained at 20 to 35 psig. The regulator weight was reduced from that of the prototype. A cross sectional schematic of the flight-type regulator is shown in Figure 11. Photographs of the regulator components in the assembled and disassembled configuration are shown in Figures 12 through 15.

The primary changes were made to provide a sealed ambient pressure reference cavity, and to modify the poppet shaft seal configuration to be adaptable to a bellows seal for future development. The diaphragm configuration remains identical, although the sealing and clamping arrangement was modified to seal the ambient reference cavity and to reduce the clamping

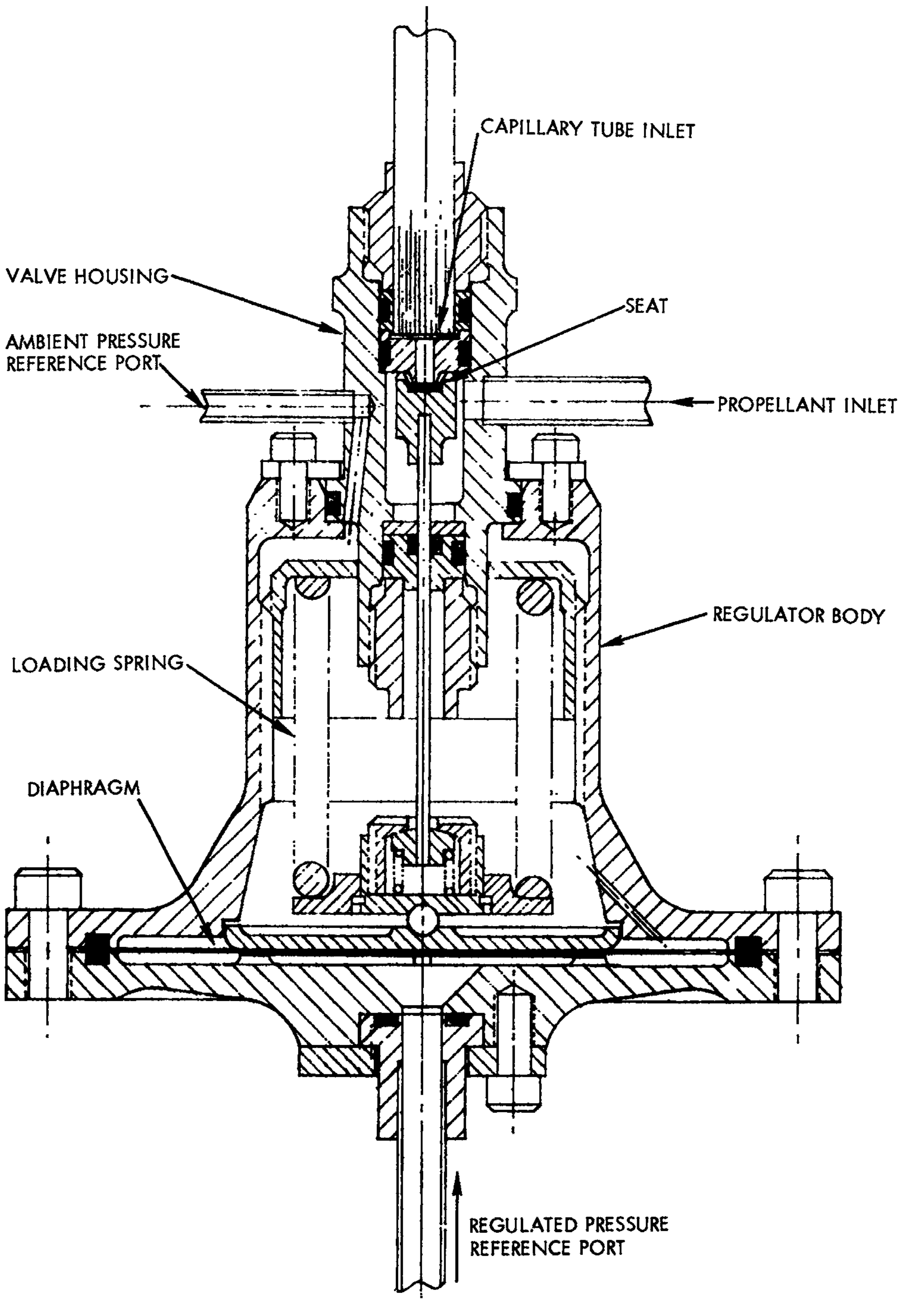


Figure 11. Flight Regulator Cross Section

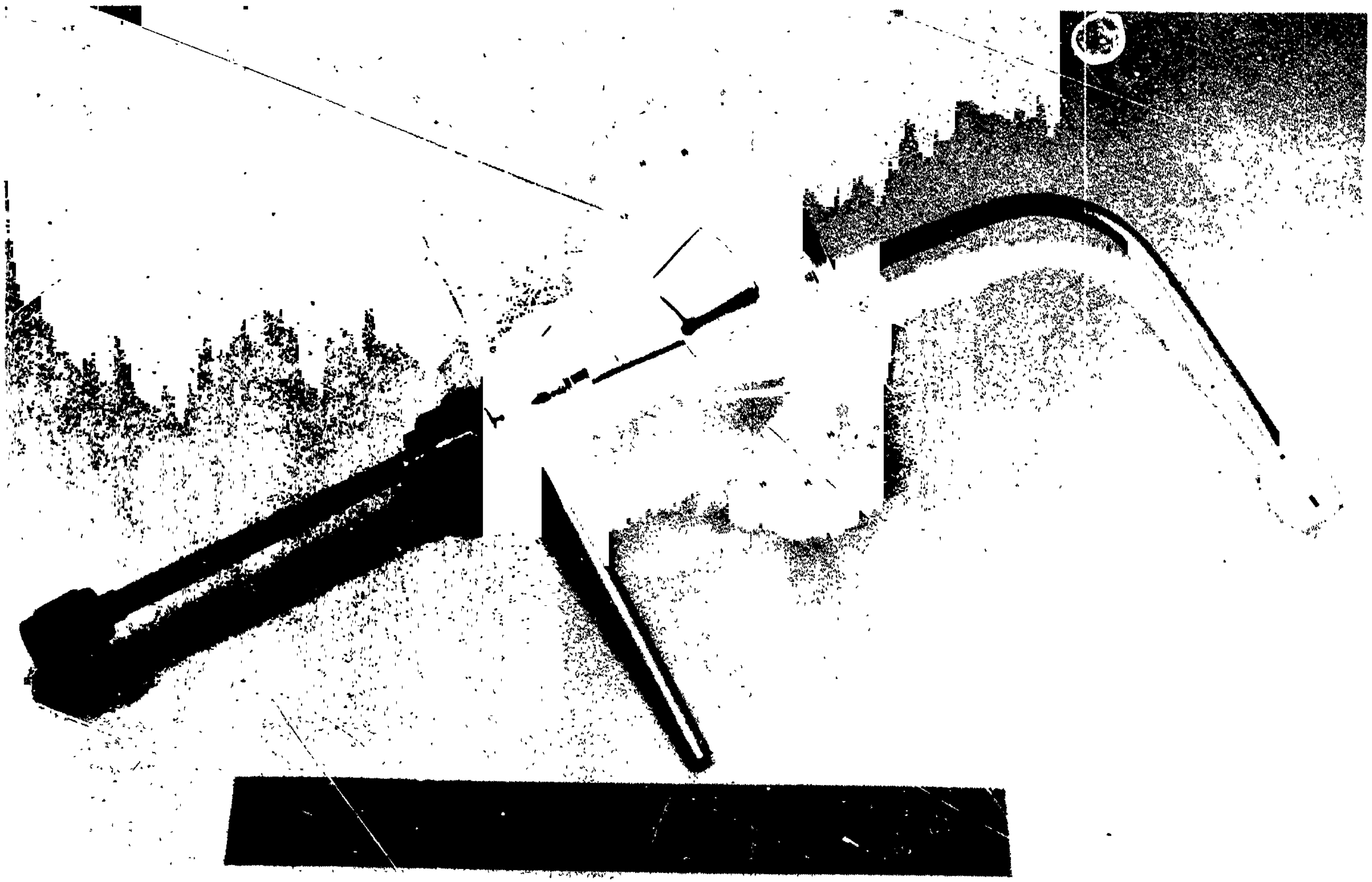


Figure 12. Flight Configuration Regulator, Valve End

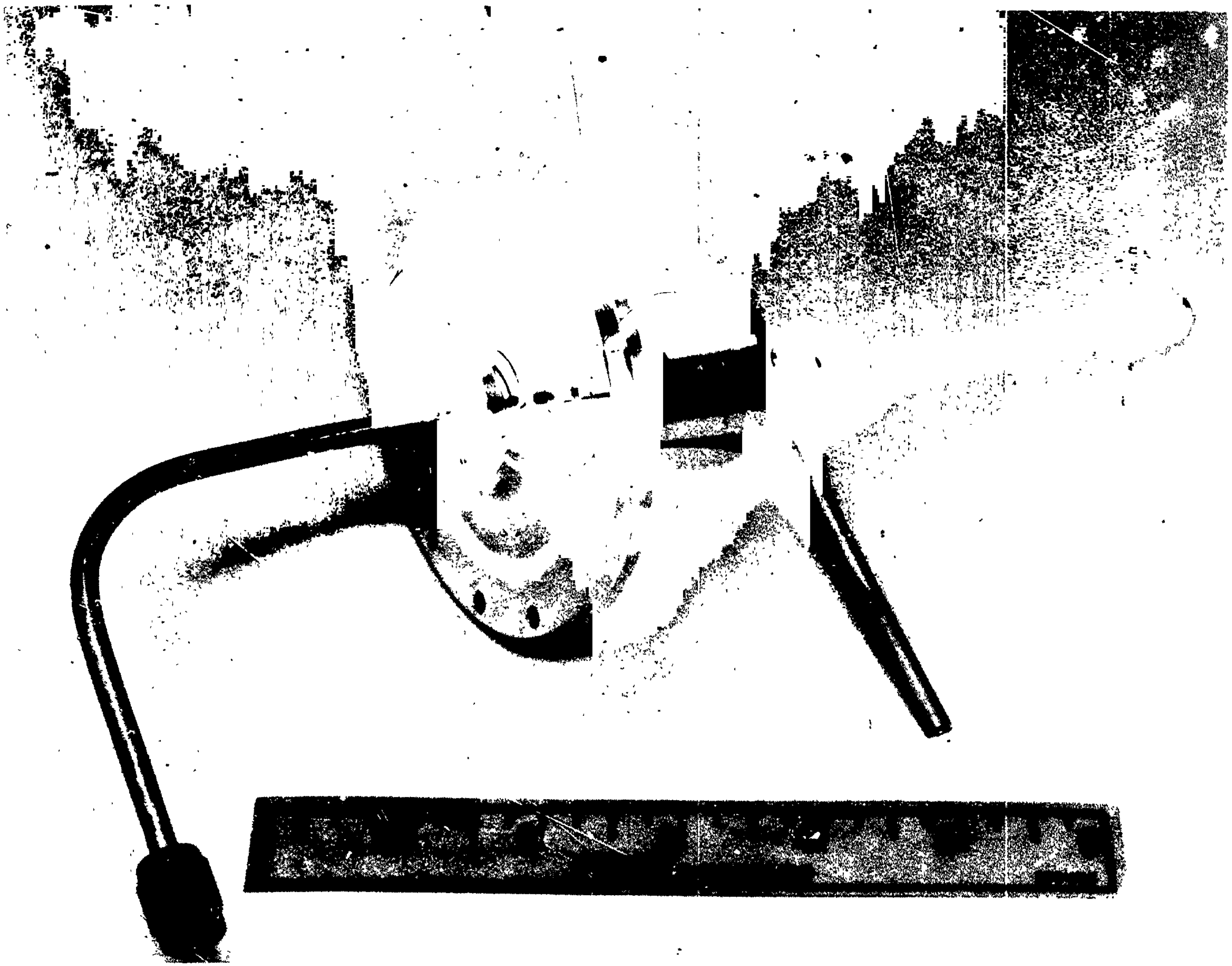


Figure 13. Flight Configuration Regulator, Diaphragm End

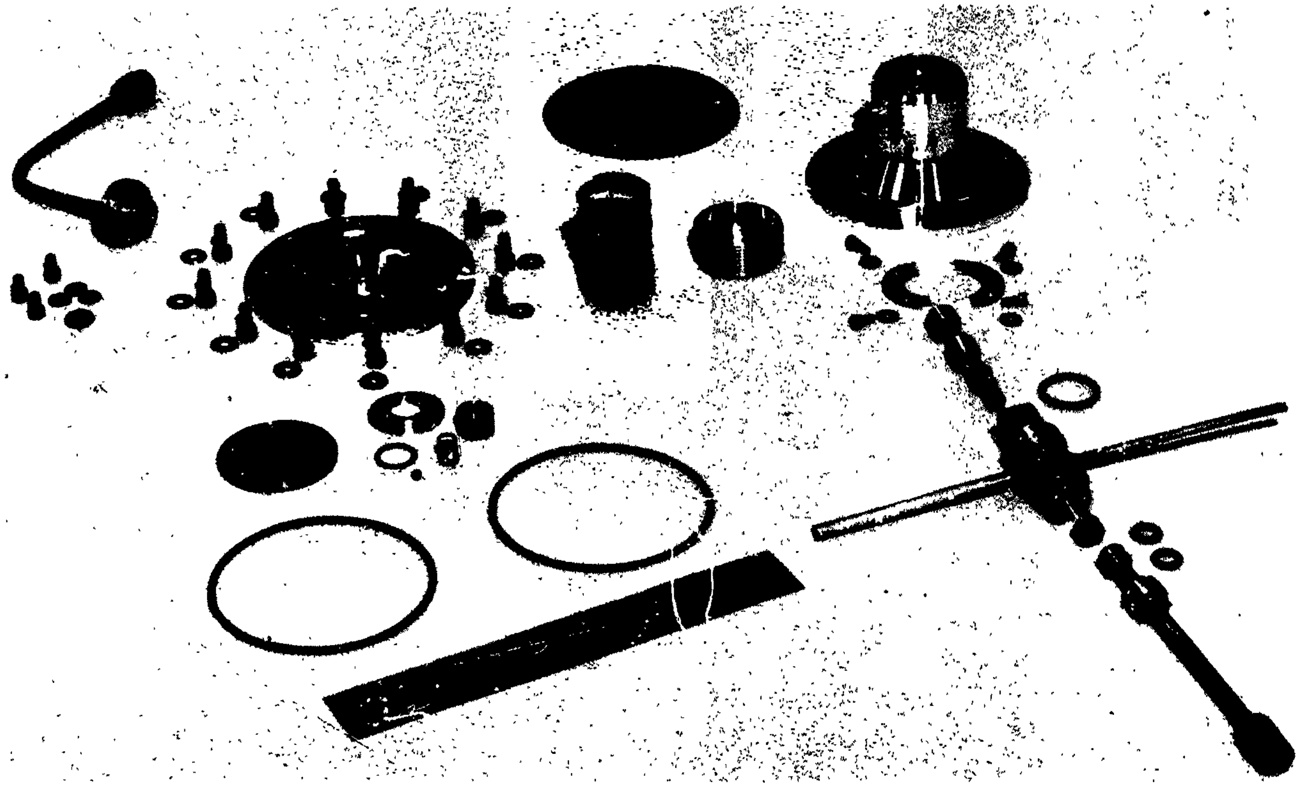


Figure 14. Flight Regulator Components

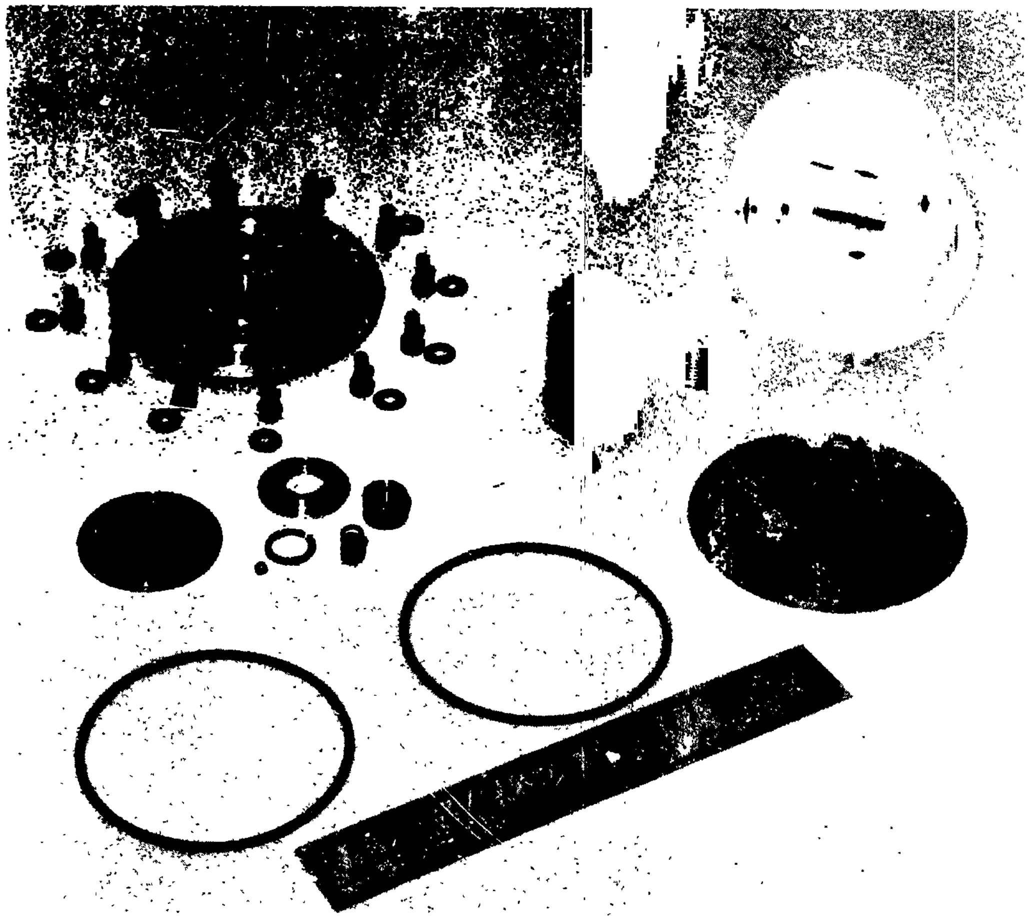


Figure 15. Flight Regulator Diaphragm Components

flange outside diameter. The regulated pressure sensing connection was changed to a single port with a face seal at the interface. No changes were made in the loading spring and over-travel mechanisms.

The poppet assembly was modified to eliminate the set screw assembly which would be undesirable in a flight component. The entire poppet was Nicrobrazed to the shaft prior to the seat molding operation. The seals and retainers were assembled on the shaft and a mechanical stop was then silver brazed at a calibrated location on the shaft tip. The assembly can be seen in Figure 15. The silver brazed stop can be removed and rebrazed if a shaft seal replacement is necessary. To accommodate this method of assembly, the spring plate was changed to a two-piece assembly using a lock ring.

The seat and capillary header design was changed to a two-piece arrangement. The seat was thereby made independent of the capillary connection. The seat diameter was increased from 0.062 inch to 0.070 inch and the inlet tube from 1/8 inch to 3/16 inch to reduce valve pressure drop.

The regulation set point adjustment method was changed to accommodate the sealed ambient reference cavity requirement. The loading spring adjustment is made by loosening the valve housing clamp. The regulator body may then be rotated without moving any of the connecting lines. Rotation of the regulator body causes rotation of the adjustment nut relative to the body. The nut is driven through the square shank of the valve housing. The design makes the adjustment possible with the regulator fully installed in the feed system. During adjustment, the valve body, loading spring and valve shaft turn as a unit, eliminating twisting between the shaft and valve body. Another change to the adjustment design is necessary if a bellows shaft seal is used in the future. A possible design configuration with the "O"-ring shaft seal replaced by a metal bellows is shown in Figure 16.

The assembly method was changed for the flight unit, in that the valve assembly was completed first. The valve was then inserted in the regulator body. The loading spring and spring plate were assembled with the lock ring. The diaphragm and end plate were then installed.

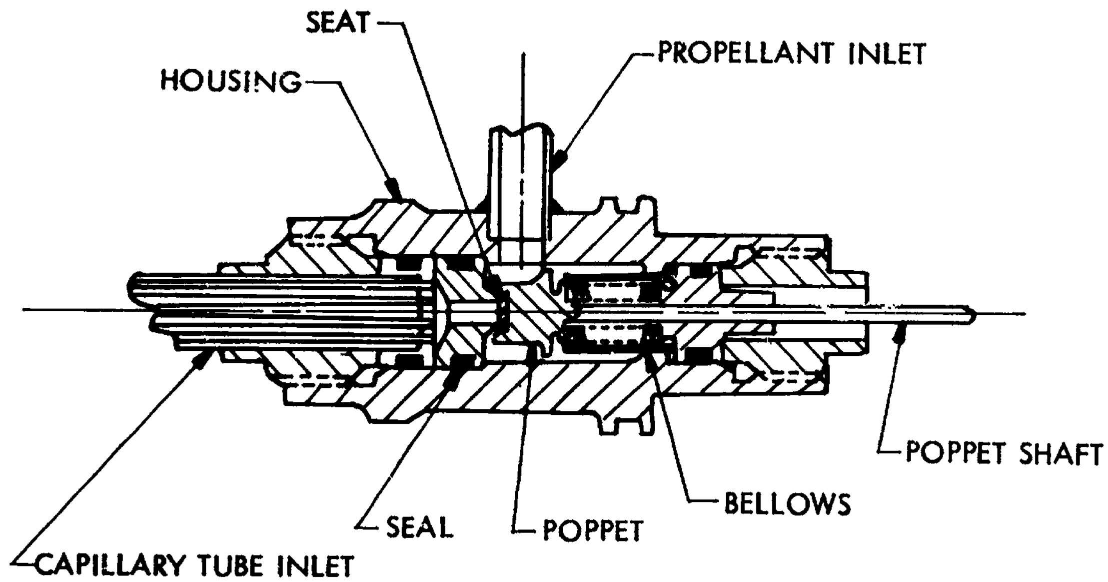


Figure 16. Bellows Sealed Poppet Shaft Cross Section

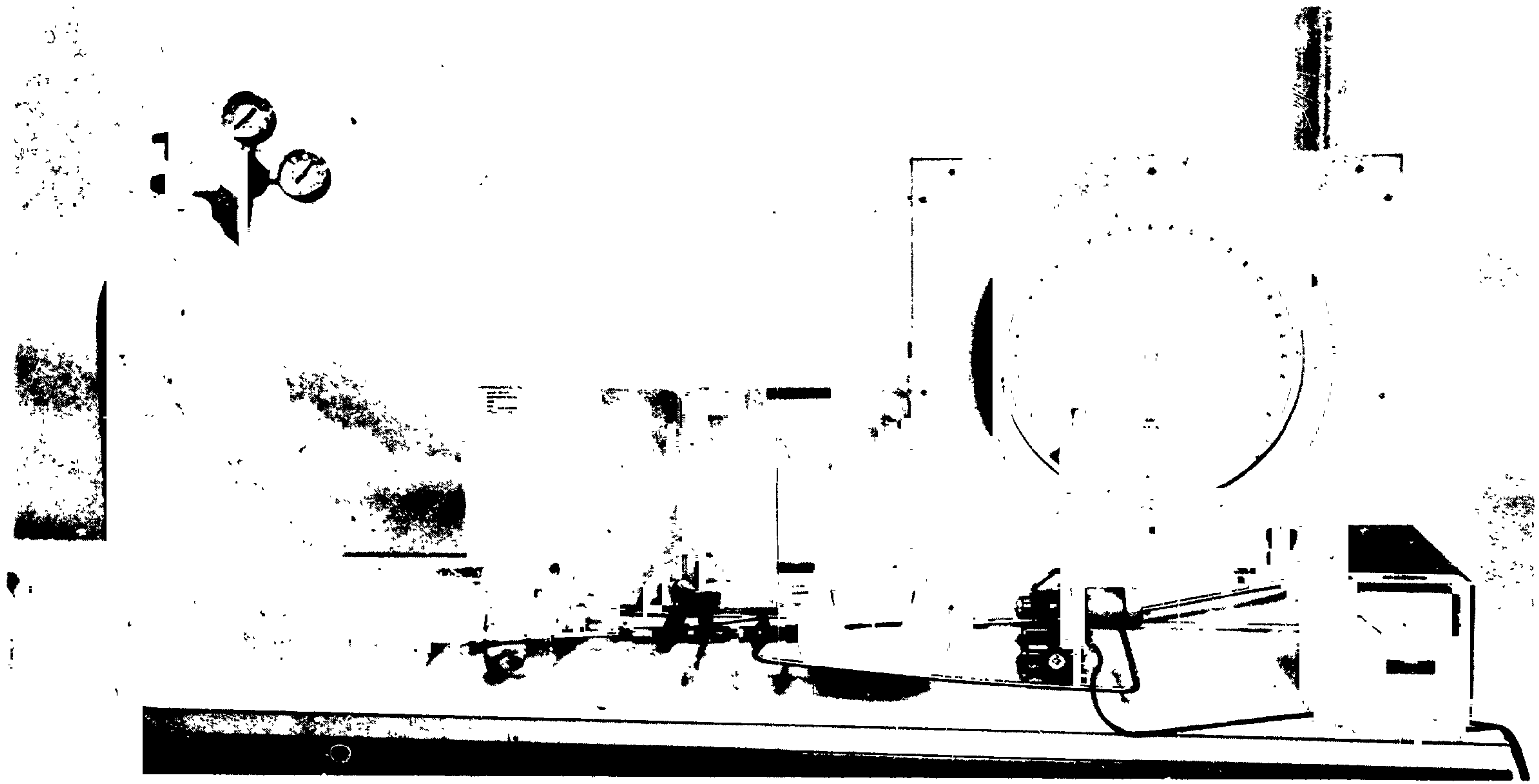


Figure 17. Acceptance Test Calibration Assembly

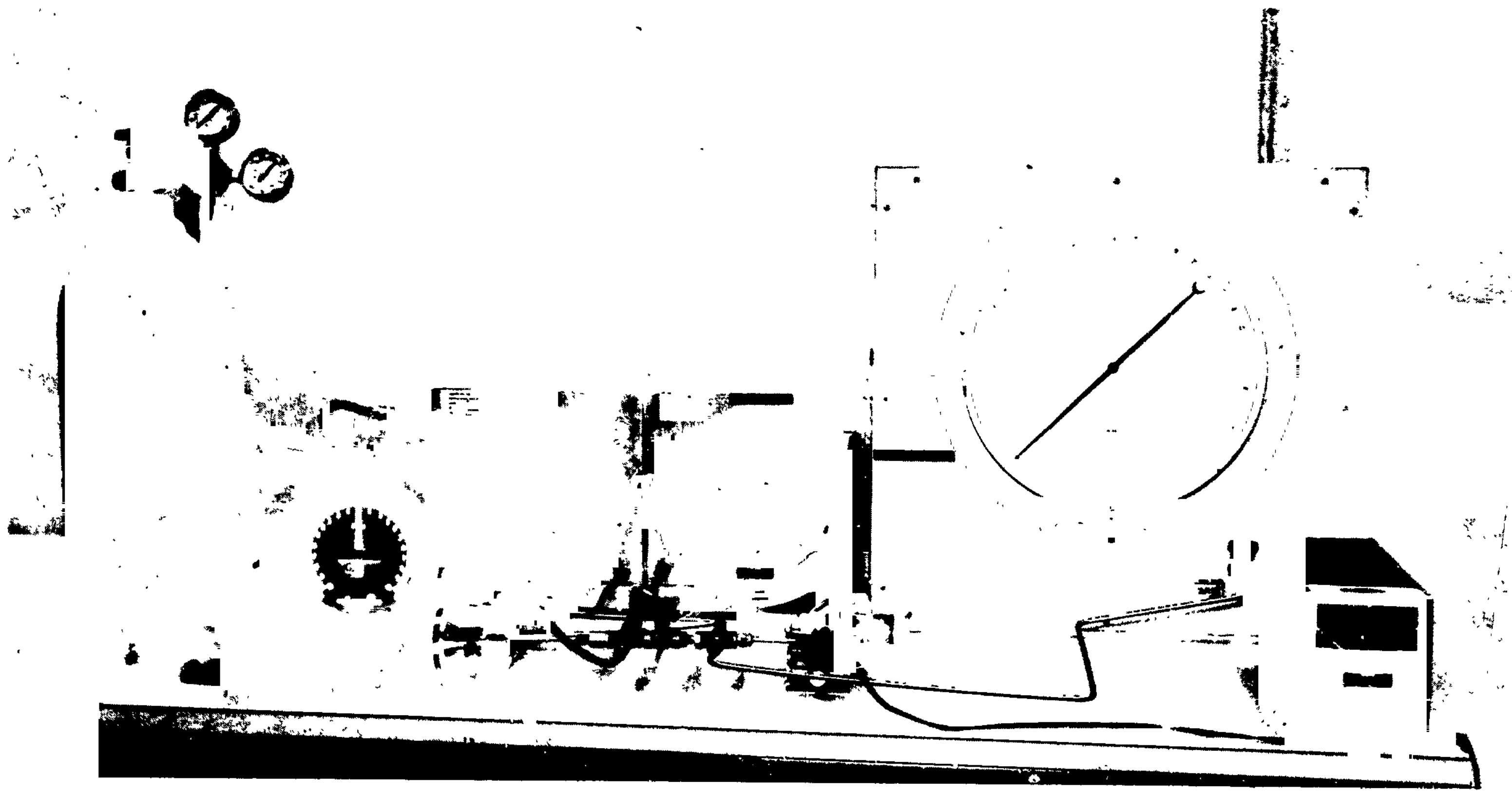


Figure 18. Acceptance Test Pressure Drop Assembly

Pertinent design features of the flight regulator are:

Seat orifice diameter	0.070 inches
Poppet stroke	0.025 inches
Diaphragm stroke	0.030 inches
Poppet shaft diameter	0.050 inches
Diaphragm effective diameter	2.0 inches
Diaphragm effective area	3.14 $inches^2$
Loading spring force at maximum design regulated pressure	110 pounds
Overtravel spring force	2.6 pounds
Regulator weight	0.69 pounds

The flight-type regulator materials are essentially unchanged from those used in the prototype. The poppet seal is identical as are all the "O" ring seals. At the time of selection, the butyl compound (SR 634-70) and bonding technique for the seal had shown no signs of deterioration in the prototype configuration over an estimated total exposure of two weeks. The exposure was with both liquid and gaseous ammonia on an interrupted basis with intervening exposures to the air. At least half the time was with liquid exposure. The poppet shaft guide insert was changed to stainless steel in place of the aluminum used in the prototype. A dissimilar metal interface was thus eliminated at the critical shaft seal location.

3.2.3 Flight-Type Regulator Test

Preliminary tests of the flight-type regulator were limited to a check of characteristics and a comparison with the prototype regulator data. No differences were observed. The unit was calibrated and the acceptance test performed. Acceptance test results are presented in Appendix IV of this report. The calibration and pressure drop setups for the regulator acceptance tests are shown in Figures 17 and 18. Regulated pressure at minimum flow rate was set at 20.05 psig and the resulting lockup pressure was 20.4 psig. No internal leakage could be detected with GN_2 at maximum inlet pressure. The pressure drop measured across the regulator with the seat wide open is shown in Figure 10. In comparison to the prototype data, the flight-type regulator pressure drop at the maximum equivalent nitrogen flow rate was reduced from 3.7 to 1.9 psid. This was due to the increase of the inlet tube and seat orifice diameters. The regulator pressure drop measurements were repeated with gaseous ammonia over a range of diaphragm back pressure. These data are shown in Figure 19.

Discussion of the flight-type regulator performance with ammonia is covered in Section 6.3 as part of the feed system performance.

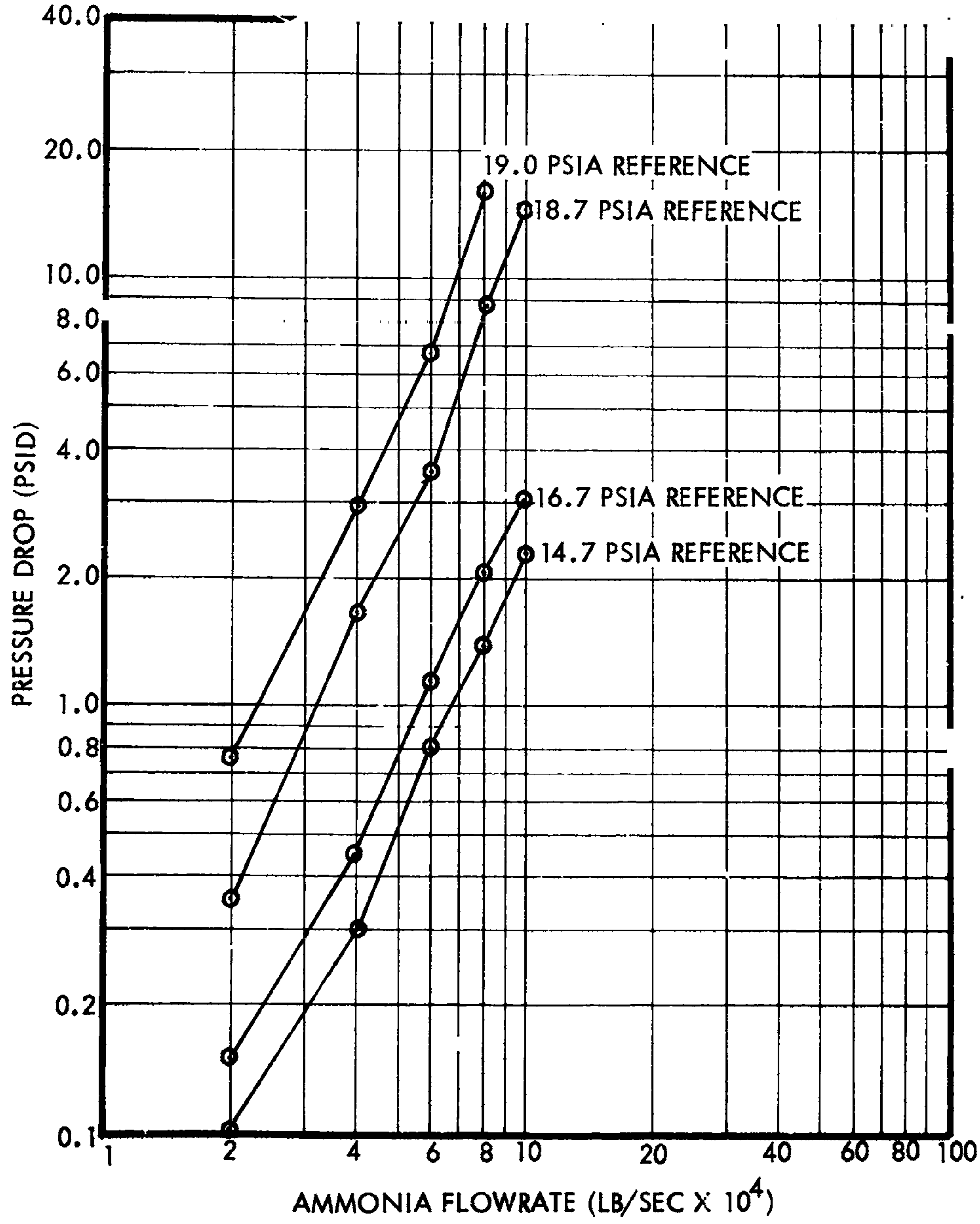


Figure 19. Flight Regulator Pressure Drop with Gaseous Ammonia

4. CAPILLARY TUBE HEAT EXCHANGER

The capillary tube heat exchanger is incorporated in the propellant system to control the delivered phase of the propellant. Together with the regulator, it also controls the delivery pressure of the propellant feed system. The individual capillary tubes of the heat exchanger are sized so that the propellant flow and heat transfer characteristics will result in the transfer of adequate heat to vaporize any liquid phase in the tubes. The capillary tubes are also sized for minimum internal volume to aid in control of delivered pressure.

4.1 CAPILLARY TUBE DESIGN AND ANALYSIS

The heat exchanger design analysis was based on the performance of individual tubes, neglecting the presence of the regulator. However, the pressure drop characteristics of the regulator were used in determining the number of capillary tubes required to meet the flow demand. The critical point used in sizing the capillary tubes was the minimum temperature at which the maximum flow demand would occur. An imposed condition at this point was that the flow regime in the tubes must be at the high end of laminar flow with liquid entering the tubes. The tube length-to-diameter ratio was adjusted so that there was sufficient area to transfer the required vaporization energy within a reasonable temperature differential. The reason for selecting this critical point and condition was to achieve stability of operation. If the instantaneous flow rate is above the critical point value, the flow will be turbulent and the potential for heat transfer will increase rapidly. For the condition of instantaneous flow rate below the critical value, the potential for heat transfer decreases at a slower rate than decrease in flow.

The flow characteristics of the propellant in the capillary tubes were determined from the pressure drop across the tubes. The pressure drop associated with a fluid flowing in a tube of constant cross-sectional area is caused by: 1) the friction force acting between the fluid and the tube wall, and 2) fluid velocity changes. The pressure drop equation in differential form is:

$$-dP = \frac{4\dot{m}^2}{\pi^2 D^4 g_c} dv + \frac{8\dot{m}^2}{\pi^2 D^5 g_c} fvdL \qquad (6)$$

where

P = pressure

$\dot{m}$ = mass flow rate

D = flow tube diameter

g_c = gravitational constant

v = specific volume

f = Fanning friction factor

L = length along flow tube

The first term on the right of the equation is the pressure drop caused by fluid velocity change. The second term is the pressure drop caused by friction. For single-phase gas flow, the integrated form of the equation is

$$P_1 - P_2 = \frac{4\dot{m}^2}{\pi^2 D^4 g_c} \left[(v_2 - v_1) + \frac{2f\bar{v}L}{D} \right] \qquad (7)$$

where

L = total tube length

$\bar{v}$ = vapor specific volume (average)

Subscript 1 refers to inlet conditions and 2 to outlet conditions. For liquid inflow, with phase change, an integrated form of the equation is:

$$P_1 - P_2 = \frac{4\dot{m}^2}{\pi^2 D^4 g_c} \left[(v_2 - v_1) + \frac{2 f_m v_m L}{D} \right] \qquad (8)$$

where the subscript m refers to mean fluid property values.
These pressure drop equations along with the equations describing the heat transfer process were used in the tube sizing.

During operation, the heat transfer process in the capillary tube is a result of forced convection. The basic premise of the capillary tube heat exchange concept is that the tubes have relatively small diameters and utilize the maximum available pressure drop. Thus, convection forces are much greater than gravitational forces, and solution to the heat transfer process within the tubes will be independent of gravitational forces.

The heat transfer process with liquid inflow is accomplished by a phase change; thus, the heat transferred to the ammonia is through a combination vapor and liquid film on the capillary tube wall. This combined-phase film can be treated by using an effective thermal conductivity. For laminar regime heat transfer,

$$N_{Nu} = \frac{hD}{k_{eff}} = \text{Nusselt number}$$

where

N_{Nu} = 3.68 is derived on the basis of assumptions which most nearly describe conditions encountered in the tubes.

h = heat transfer coefficient

D = tube diameter

k_{eff} = effective thermal conductivity

The effective thermal conductivity, k_{eff}, can be approximated by

$$k_{eff} = 0.3k_v + 0.7k_\ell$$

where

k_ℓ = thermal conductivity of liquid phase

k_v = thermal conductivity of vapor phase

The condition that must be satisfied in the heat transfer analysis is:

$$q = \dot{m}\, h_v \leq h\, \pi D\, L\, (T_w - T_b) \qquad (9)$$

where

q = heat to vaporize ammonia

$\dot{m}$ = mass flow rate

h_v = heat of vaporization

T_w = tube wall average temperature

T_b = ammonia average temperature.

The results of the pneumatic and thermal analysis on individual capillary tubes indicated that tubes with diameter in the range of 0.016 to 0.018 inch and lengths in the range of 36 to 42 inches would satisfy the system requirements. These results are based on a delivery pressure of 20 psia.

At the critical design point, the flow rate with liquid entering the tube would be in the range of two to three times the flow rate with vapor entering the tube at the same pressure drop. Under these flow conditions, the temperature difference, $(T_w - T_b)$ from equation (9), required for complete vaporization of the ammonia is in the range of 26 to 36°F. However, because of the presence of the regulator, the pressure drop across the capillary tubes is not constant and the average flow rate when liquid is entering the capillary tubes is the same as for the vapor condition. With this condition, the temperature difference required to insure vaporization of the ammonia is in the range of 12 to 15°F. The minimum propellant outlet temperature from the capillary tubes will correspond to -16°F, which is the saturation temperature at the pressure of 20 psia. The corresponding bulk average propellant temperature in the capillary tubes will be 0°F under minimum heat transfer conditions. The result of these values indicate that it is possible to reduce the tank wall temperature to approximately 15°F before the heat transfer requirement could not be satisfied and liquid would exhaust from the capillary tubes. At a maximum flow starting temperature of 40°F, the tank wall temperature can only decrease 25°F before incomplete vaporization will occur. This temperature drop corresponds, from Figure 3, to a flow time of 412 seconds.

With no pressure regulator, the total number of capillary tubes required to maintain the flow rate of 1×10^{-3} lb/sec at 35°F tank temperature (the lowest temperature attained during this flow) is in the range of 16 to 20, depending on the tube diameter and length. However, because of the pressure drop through the regulator, an additional two to three tubes are required to maintain the flow rate.

4.2 CAPILLARY TUBE EXPERIMENTS

Flow experiments with individual capillary tubes (series 300 stainless steel) were performed to verify the design calculations. The design calculations are approximations because of the uncertainties in the average value of the propellant physical properties used, specifically for the condition where liquid enters the capillary tubes. Additionally, there are deviations in the internal diameter of the flow tubes from their nominal value unless they are of precision bore. A small deviation in diameter can have a large effect on mass flow rate, because the mass flow rate is proportional to the diameter to the 2.67 power in the turbulent flow regime and the 4.0 power in the laminar flow regime. Because of the cost and delivery schedule of precision bore tubing, the analysis was performed for a range of tube sizes, and the selection of the tube size and number for the system was based on the experimental results.

A schematic of the experimental assembly for testing the flow characteristics of individual capillary tubes is shown in Figure 20. The capillary tubes were bonded to a spherical ammonia storage vessel with a volume of 113 cu. in. The capillary tube bonding material was ECCOBOND 57C, a silver doped epoxy, which is a product of Emerson and Comings, Inc. Either liquid or vapor phase ammonia could be discharged from the storage tank into the capillary tube. The capillary tube exhausted directly into a glass tube section, which served as a sight glass for observing the propellant discharging from the capillary tube. The downstream or delivery pressure from the capillary tube was controlled by a hand valve. The flow rate through the capillary tubes was measured by collecting the propellant in a calibrated volume and monitoring the time rate of pressure change in volume. The pressure at the inlet to the capillary tube during a test was measured on a 0-300 psig pressure gauge. This pressure was varied by changing the propellant temperature in the storage vessel. The downstream pressure of the capillary tubes was monitored with a 0-20 psig pressure gauge.

The capillary tubes that were used in the experiment had the following dimensions:

Internal Diameter (inch)	Length (inches)
0.016	36.0
0.016	48.0
0.017	36.0
0.017	42.0
0.018	42.0

This set of tubing covered the size range that was analytically determined to meet the system requirements.

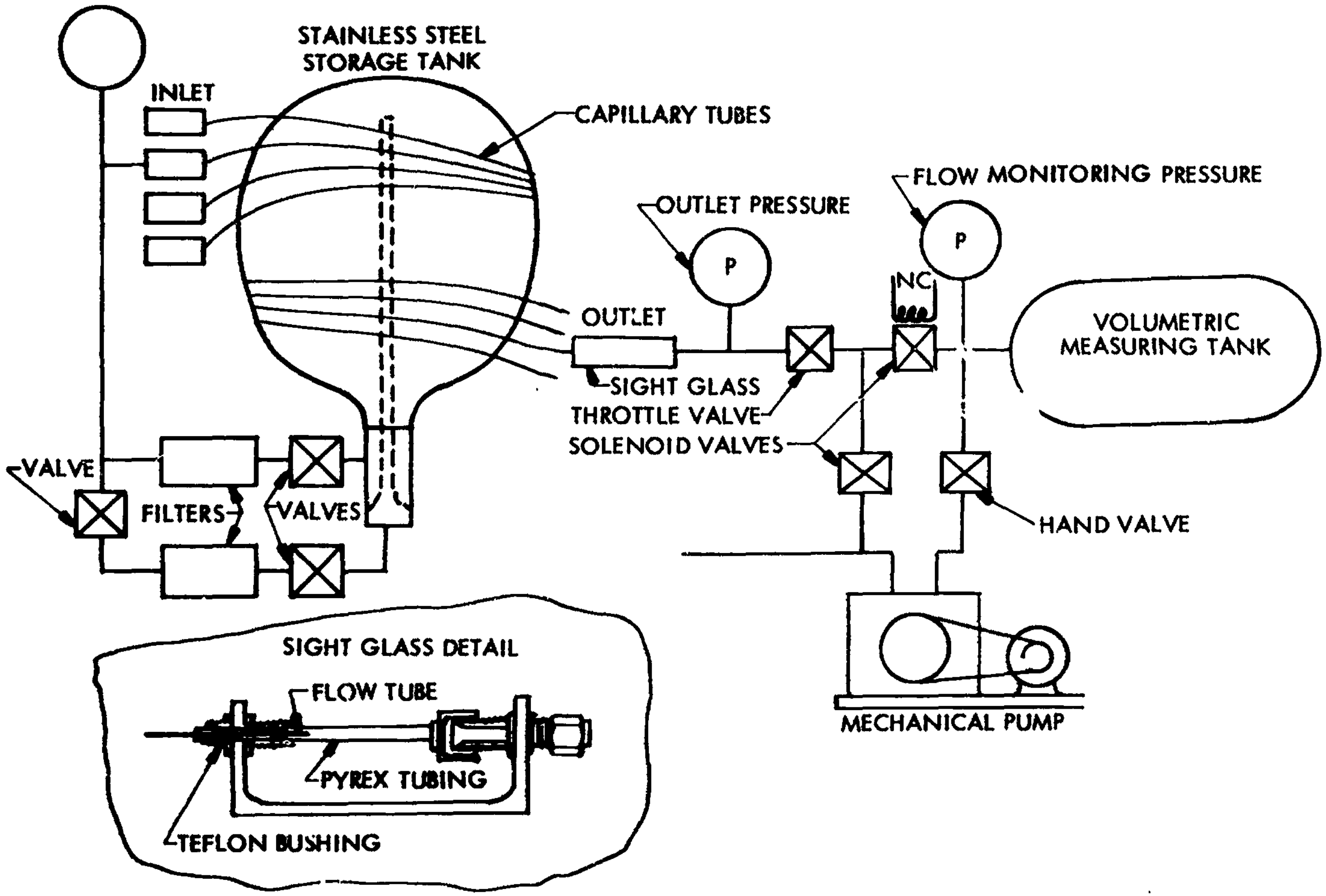


Figure 20. Capillary Tube Flow Test System

4.3 CAPILLARY TUBE TEST RESULTS

Each of the four capillary tubes were tested over an inlet pressure range with both liquid and vapor as the entering ammonia phase. The results of these tests are shown in Figures 21 through 25. The downstream pressure maintained during all of the test runs was 20 psia. During each individual test run, the inlet pressure to the capillary tube decreased over the time period required to have an adequate pressure change in the calibrated volume for obtaining a flow measurement. Thus, the data points represent the average inlet pressure over the flow time period. A minimum flow time, independent of flow rate, was required to establish equilibrium conditions in the downstream flow and monitoring sections. Because of this factor, the change in inlet pressure varied with flow rate. With vapor inflow the variation in inlet pressure was less than 2 psi. With liquid inflow, during which the flow rate was higher than for the vapor case, the inlet pressure decrease during a run was in the range of 2 to 10 psi. This pressure change accounts for the larger scatter in the liquid data, especially at the higher tank pressures.

The discharge fluid from the capillary tubes, when liquid was the inlet phase, was observed in the sight glass during the flow run. No liquid phase ammonia was noted in the exhaust during any of the runs. There was, however, an occassional fog in the discharge toward the end of those runs in which there was a large decrease in inlet pressure during the run. This fog appeared periodically and would persist for a fraction of a second. Its presence generated a negligible effect on the downstream pressure during a run. Because it did appear at conditions that were in excess of the system requirements, it would not be generated during operation of the finalized system within design specification.

As a result of these experiments, the tube selected for the feed system had an ID of 0.017 inch and a length of 36 inches. At a minimum tank temperature for maximum flow rate of 35°F, the propellant saturation pressure is 66.3 psia. The condition of vapor phase entering the capillary tubes will determine the number of tubes required to meet the flow demand.

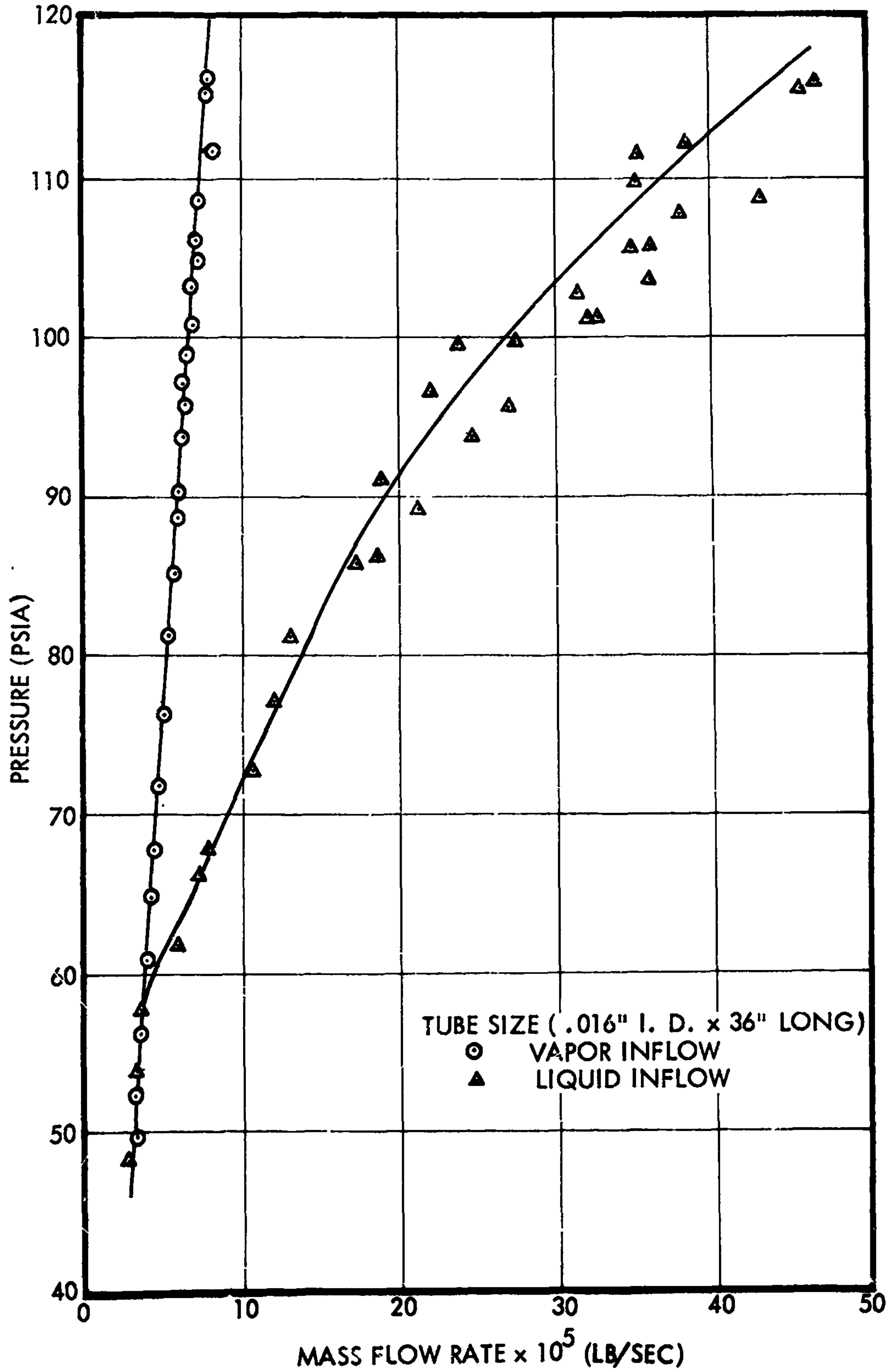


Figure 21. Capillary Tube Flow Characteristics (0.016" I.D. x 36" Long)

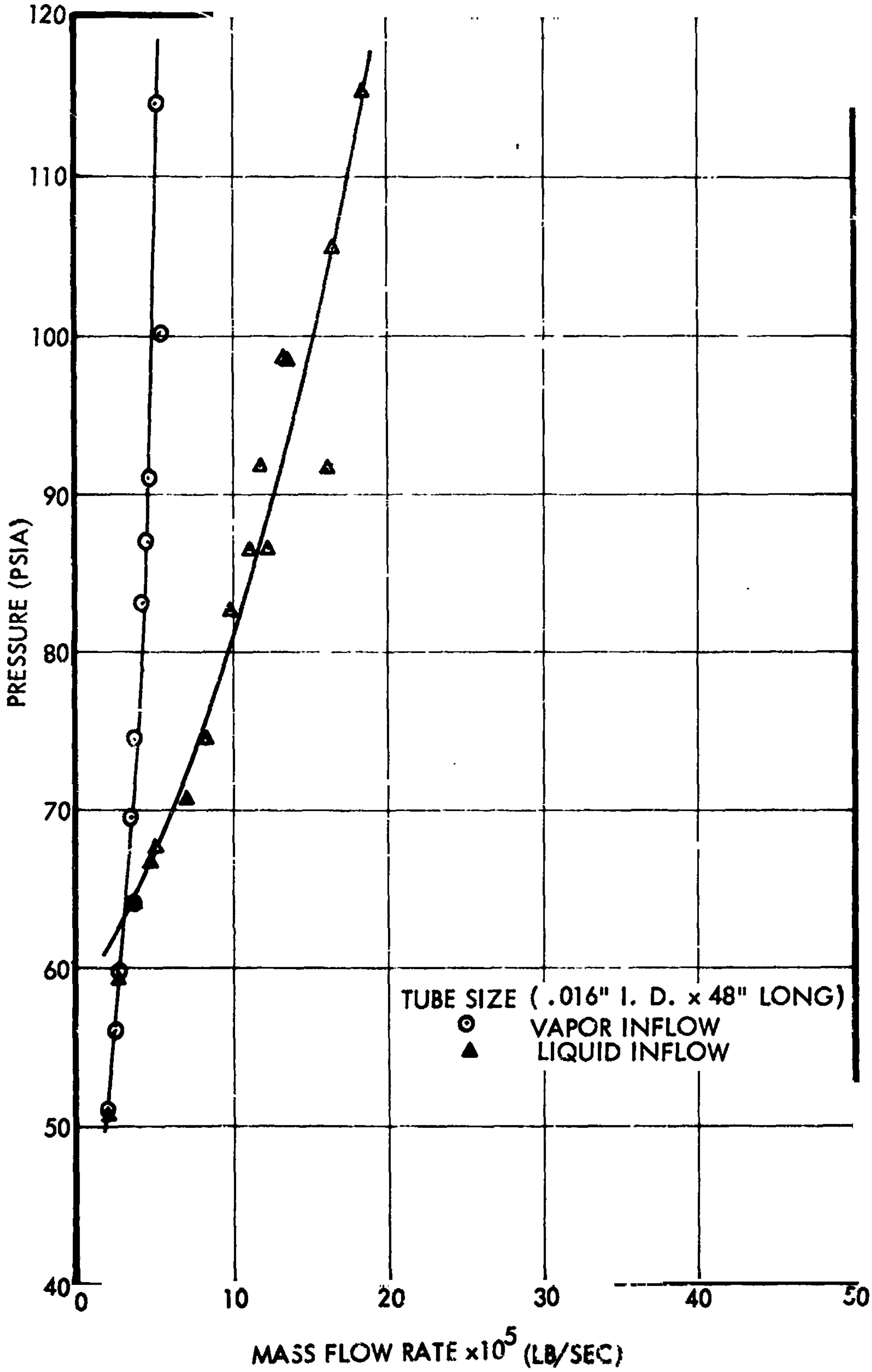


Figure 22. Capillary Tube Flow Characteristics (0.016" I.D. x 48" Long)

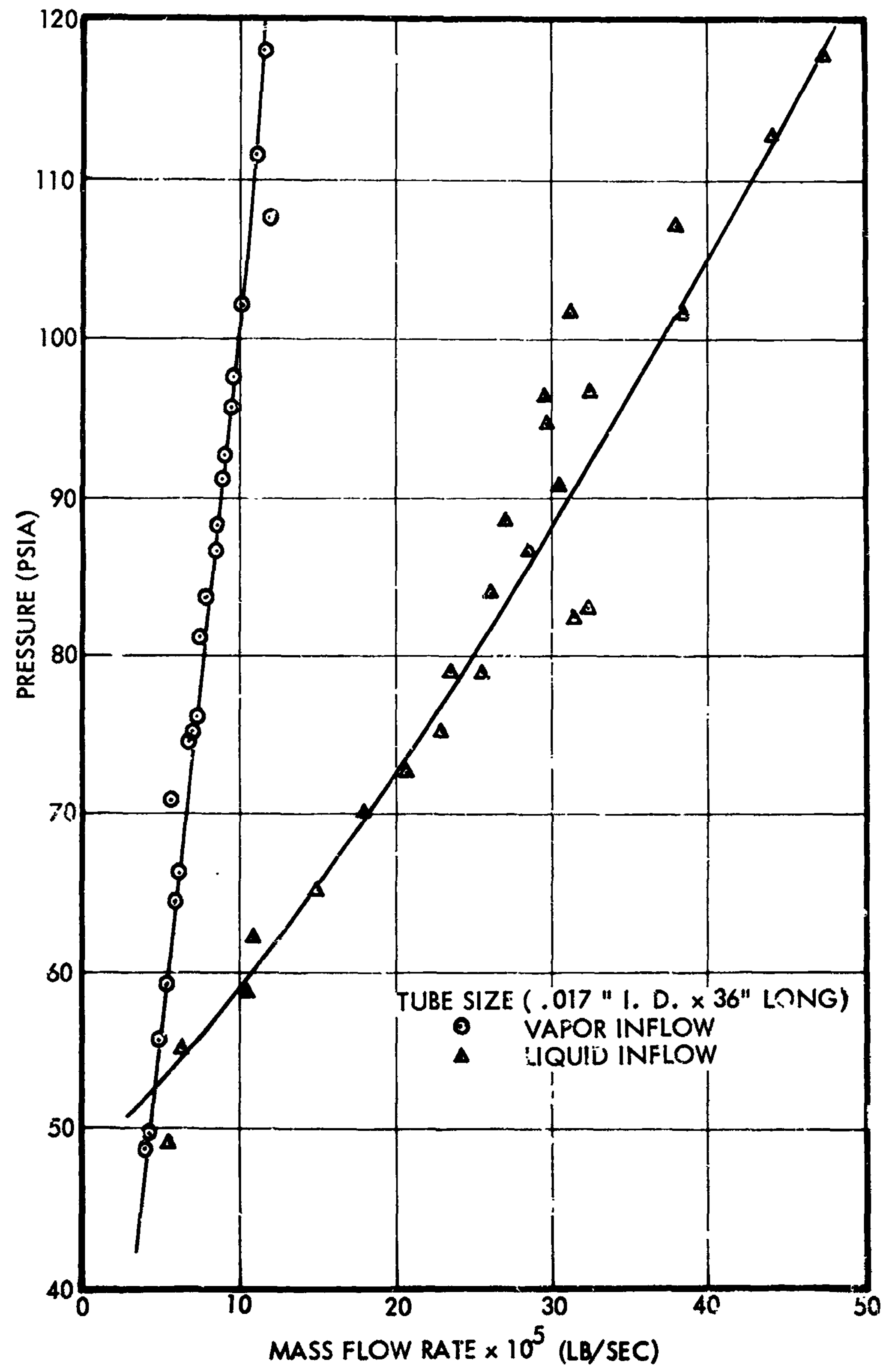


Figure 23. Capillary Tube Flow Characteristics (0.017" I.D. x 36" Long)

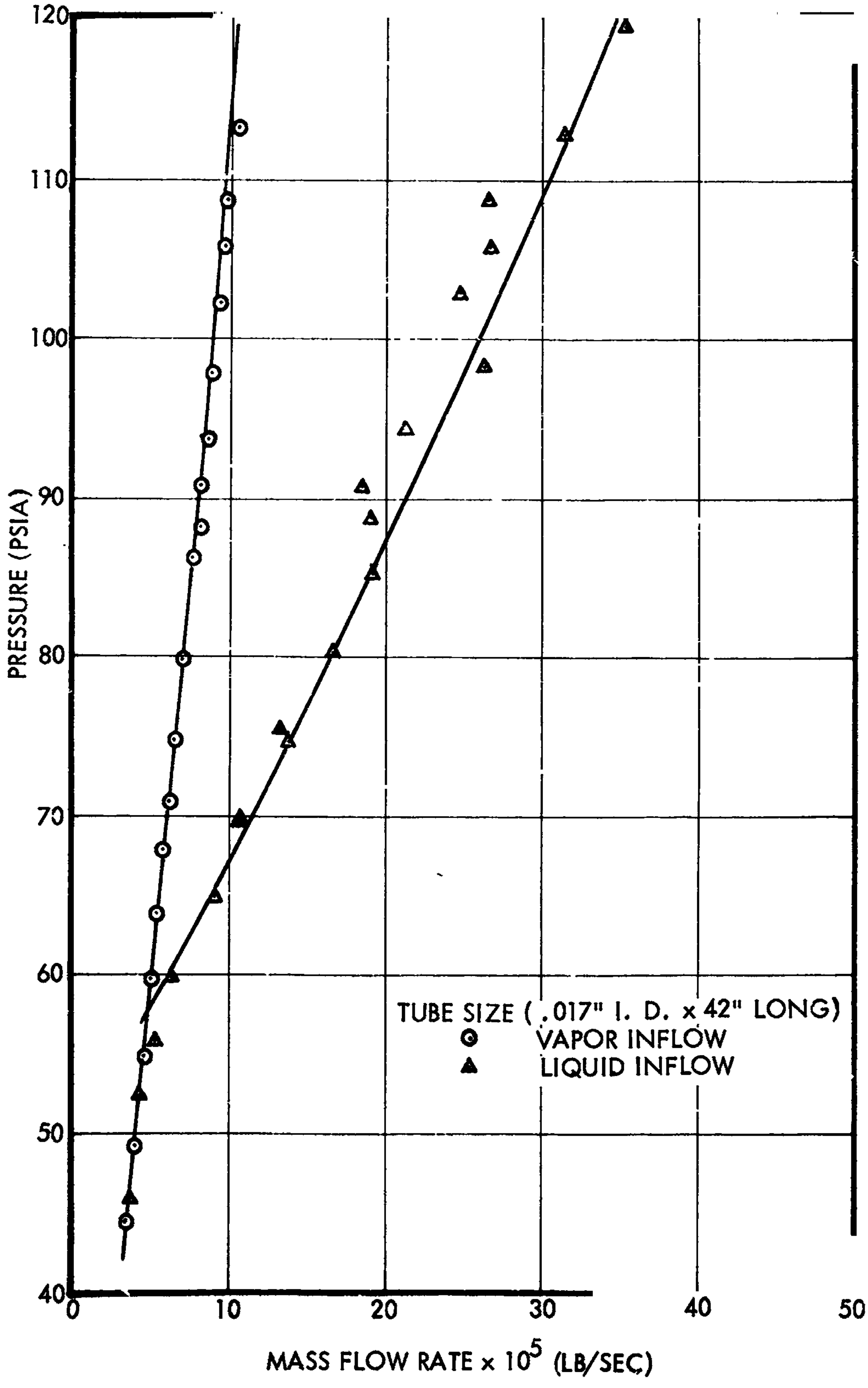


Figure 24. Capillary Tube Flow Characteristics (0.017" I.D. x 42" Long)

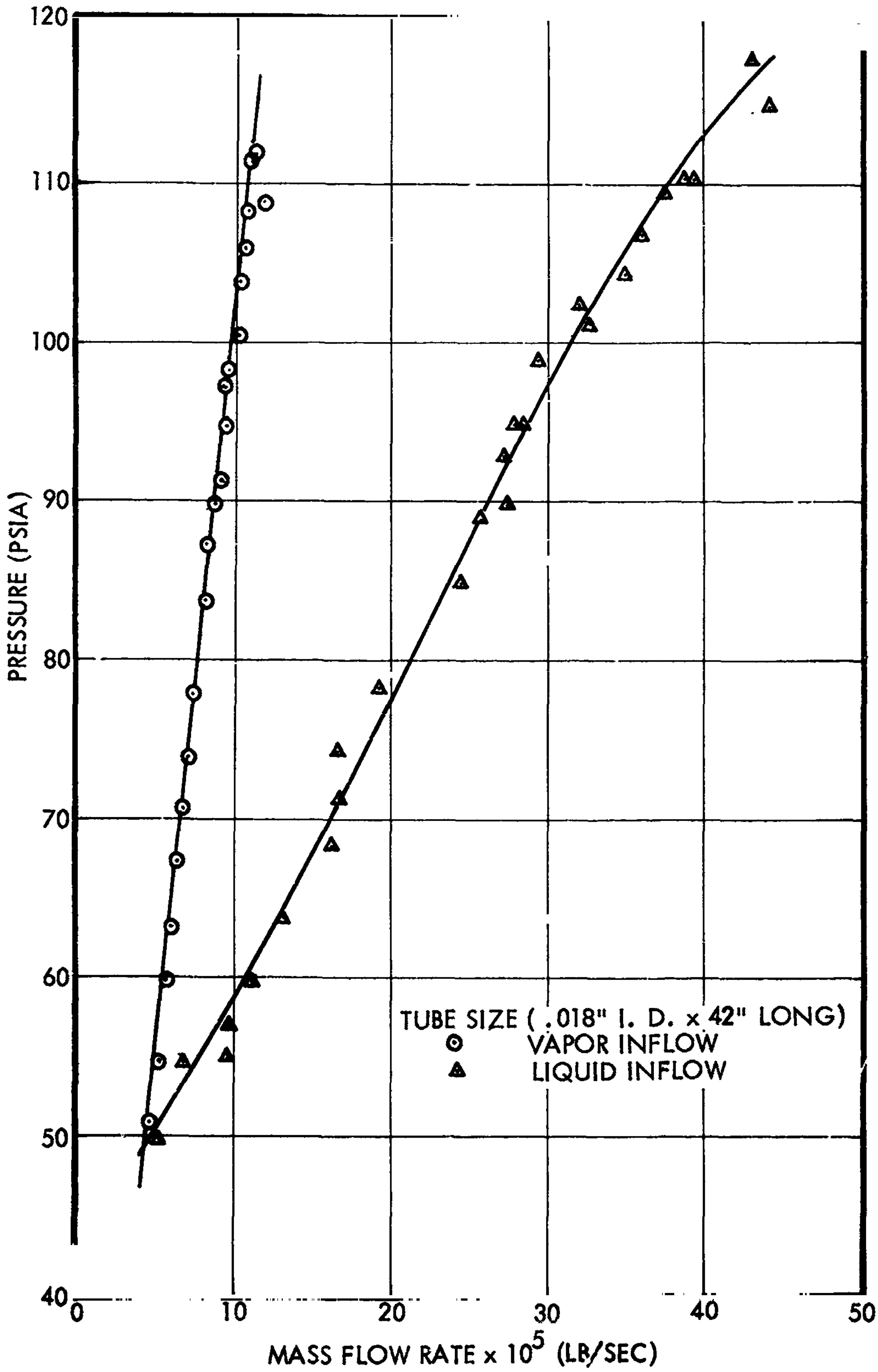


Figure 25. Ca illary Tube Flow Characteristics (0.018" I.D. x 42" Long)

The pressure drop through the prototype regulator with vapor at the maximum flow rate (Section 3.1.3.1) is 3.7 psi. Therefore, the minimum inlet pressure to the capillary tubes (at the maximum flow rate) will be 63.6 psia. For the tubes selected, the flow rate with this inlet pressure, from Figure 23, is 5.08×10^{-5} lb/sec. The maximum flow rate of 1×10^{-3} lb/sec can be maintained with 20 capillary tubes. This was the number selected for the system.

5. PROTOTYPE FEED SYSTEM

The prototype feed system served as a test vehicle for verification of feed system performance and component interactions prior to fabrication and assembly of the final flight configuration. Specific test objectives included:

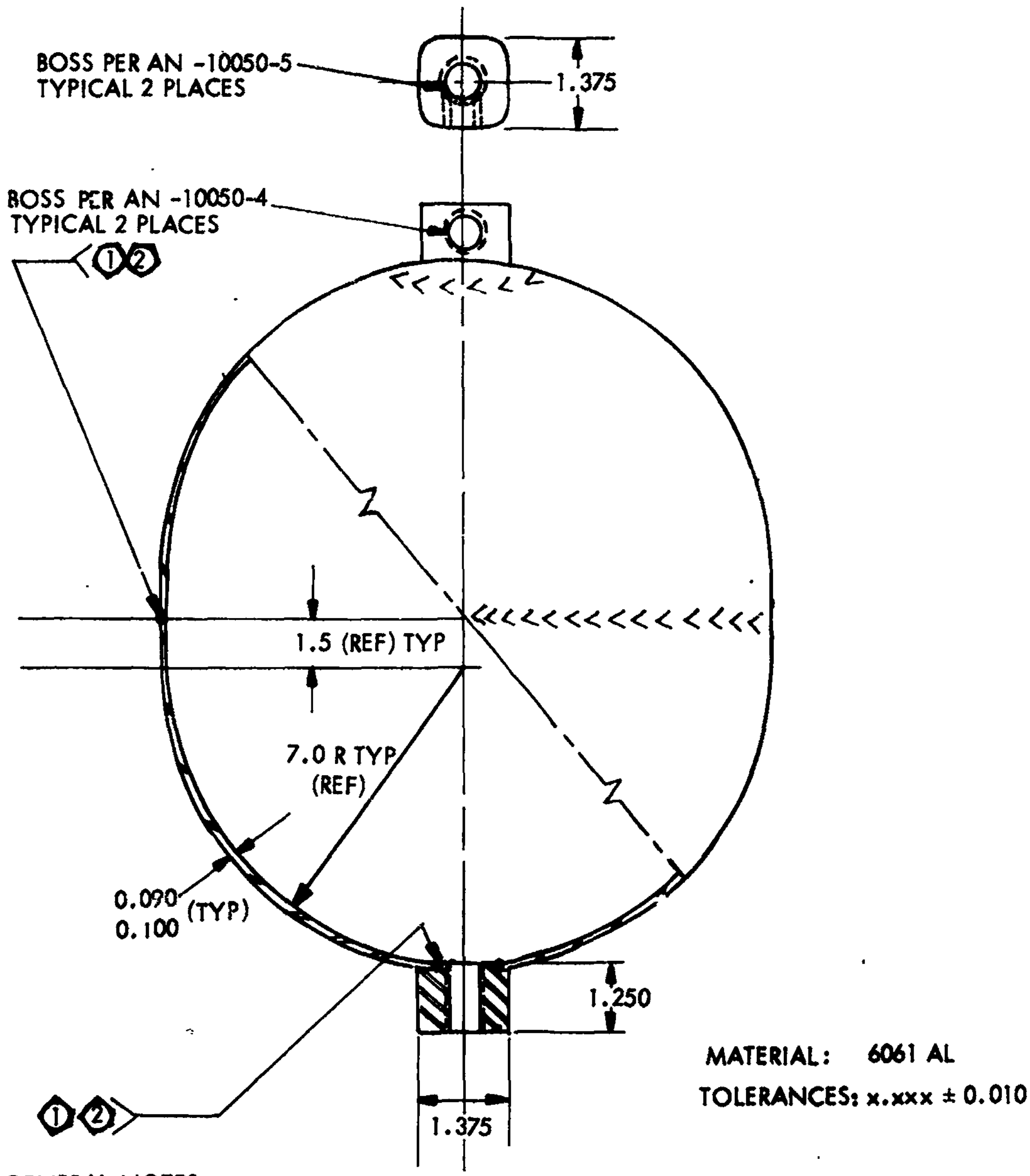
- Evaluation of the interactions between the pressure regulator and the capillary tubes
- Determination of system flow capacity and regulation limits
- Verification of operational stability
- Verification of the adequacy of the size and number of capillary tubes
- Determination of the need for, and size of, a downstream plenum volume
- Evaluation of heat transfer characteristics

The prototype system was fabricated to closely resemble the final flight configuration in order to maximize the validity of the test results.

5.1 PROTOTYPE SYSTEM ASSEMBLY

The propellant storage tank for the prototype feed system was manufactured from hemispherical tank halves of 6061 aluminum. Each tank half had a radius of 7 inches and a nominal thickness of 0.10 inch. The tank halves included a straight cylindrical section, 1.5 inches in length. The end bosses were welded to the tank halves per MIL-W-8604. The welds were X-rayed per MIL-STD-453 and then helium leak checked. The tank halves were joined by a girth weld and the assembly was solution heat treated and aged to T6 condition (per MIL-H-6088). The weld areas were X-rayed prior to, and dye penetrant tested after, the heat treatment.

The tank was proof tested for 5 minutes at 320 psig. Following the proof test, the tank was cleaned per TRW Specification PR2-2, Level 1. The volume of the prototype propellant tank is 1.03 cu. ft. A schematic of the prototype propellant tank is shown in Figure 26.



GENERAL NOTES:

1. WELD PER MIL-W-8604
2. X-RAY PER MIL-STD-453
3. SOLUTION HEAT TREAT AND AGE PER MIL-H-6088 TO 6061 T 6 COND.
4. DYE PENETRANT INSPECT PER MIL-I-6866
5. HYDROSTATIC PROOF TEST AT 320 PSIG
6. HELIUM LEAK TEST
7. CLEAN PER PR2-2, LEVEL 1

DESIGN CRITERIA:

MEDIUM	ANHYDROUS AMMONIA
OPERATING PRESSURE	212 PSIA MAX
PROOF PRESSURE	320 PSIG
BURST PRESSURE	465 PSIA MIN
VOLUME	1780 IN^3
LEAKAGE	3×10^{-5} SCC/SEC He MAX.

Figure 26. Prototype Propellant Tank Layout

The capillary tube bundle contained 20 tubes, each with an internal diameter of 0.17 inch, external diameter of 0.033 inch, and length of 36 inches. Tube material was type 321 stainless steel. The capillary tubes were cleaned per PR2-2, Level 0, and then flow checked to ascertain full flow capacity for each individual tube. The interface between the capillary tubes and the pressure regulator is shown in Figure 4. The tube bundle end was brazed into a steel collar which in turn was soldered to the regulator outlet orifice. The other end of the capillary tubes was terminated in a drilled-out 1/4-inch AN plug. The capillary tube assembly was recleaned and flow checked prior to attachment to the propellant tank.

The capillary tubes were bonded to the propellant tank with ECCOBOND solder 57C, a silver doped epoxy which has a high thermal conductivity (greater than 200 BUT/ft^2/hr/°F/in) and bonding strength (500 psi in shear at room temperature). This is the same material that was previously used on the capillary tube experiments and later on the deliverable system.

The prototype system was assembled with two lines feeding the pressure regulator from the tank. This arrangement allowed selection of either vapor or liquid withdrawal with the tank maintained in a vertical position. In addition to the propellant tank and the pressure regulator, the assembly included a 113 cu.in. downstream plenum tank, an inlet filter to the regulator, a fill and drain valve on the propellant tank, pressure transducers to monitor storage tank and regulated system pressure, and various propellant lines and shut-off and throttle valves. The propellant tank, pressure regulator and the plenum tank, together with the associated plumbing, were enclosed within a vacuum chamber during the prototype testing. A schematic of the prototype system and the test setup is shown in Figure 27. Schematics of the propellant filter and the fill valve are shown in Figures 28 and 29.

5.2 PROTOTYPE SYSTEM TEST RESULTS

The prototype feed system tests were conducted with an initial ammonia fill of 8.0 pounds. This is equivalent to 20% of full tank capacity at 70°F. Testing was conducted with vapor and liquid phase ammonia supplied to the pressure regulator.

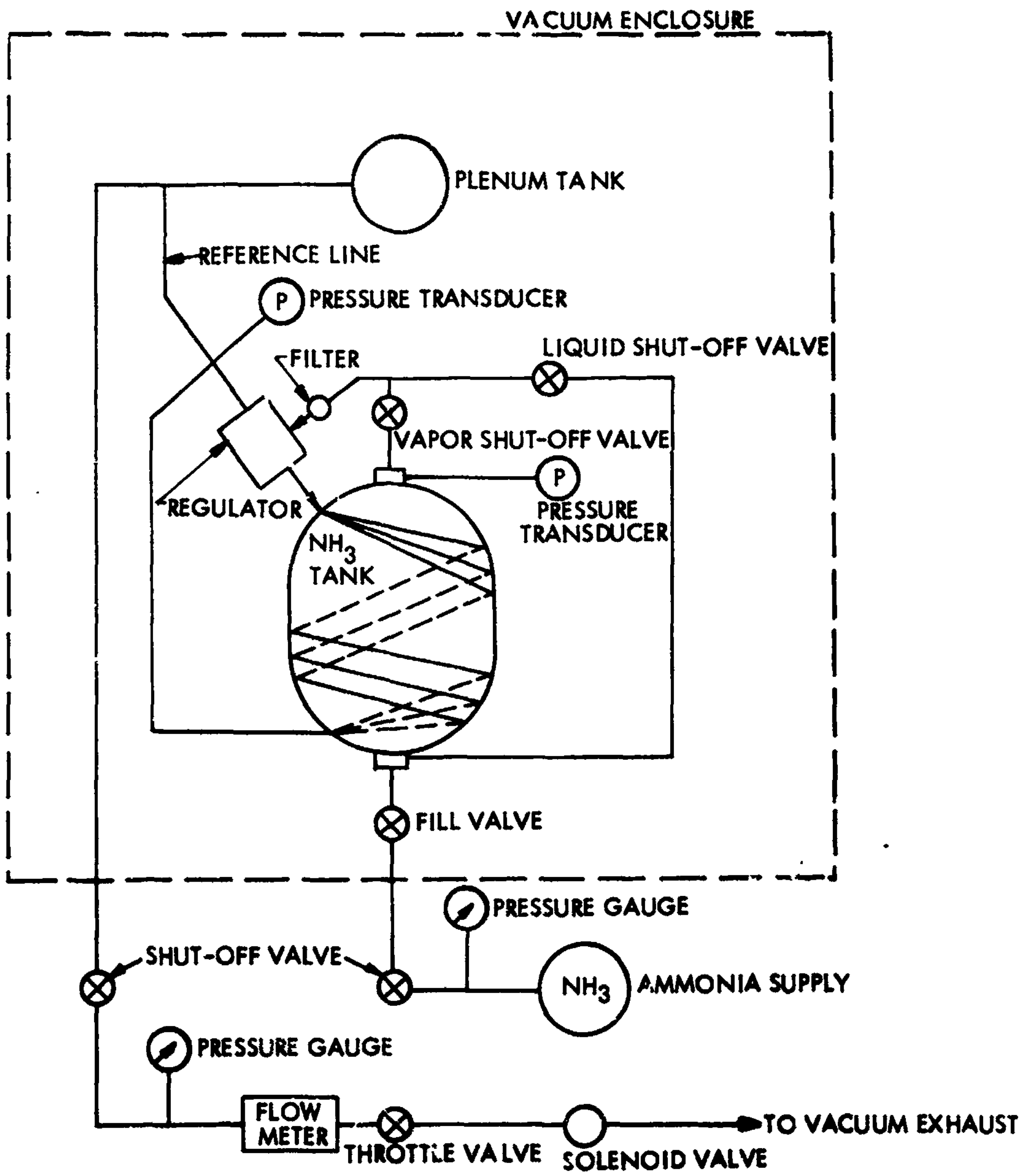


Figure 27. Prototype System Test Schematic

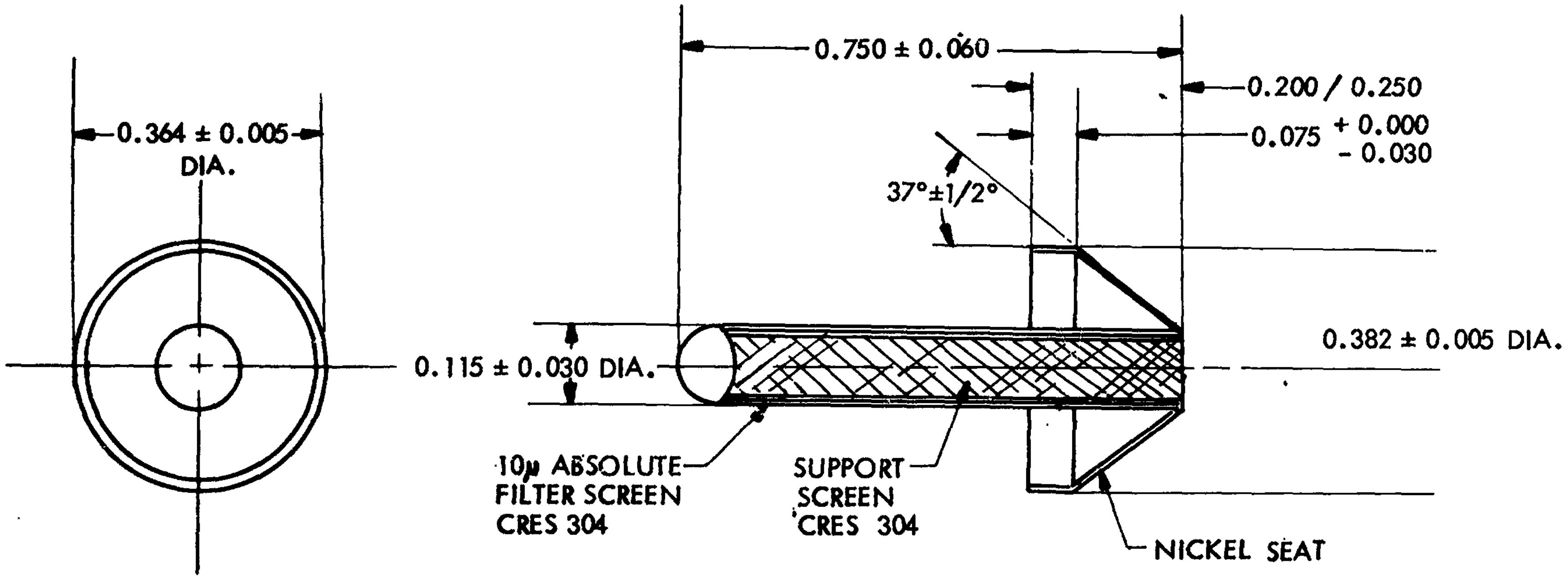
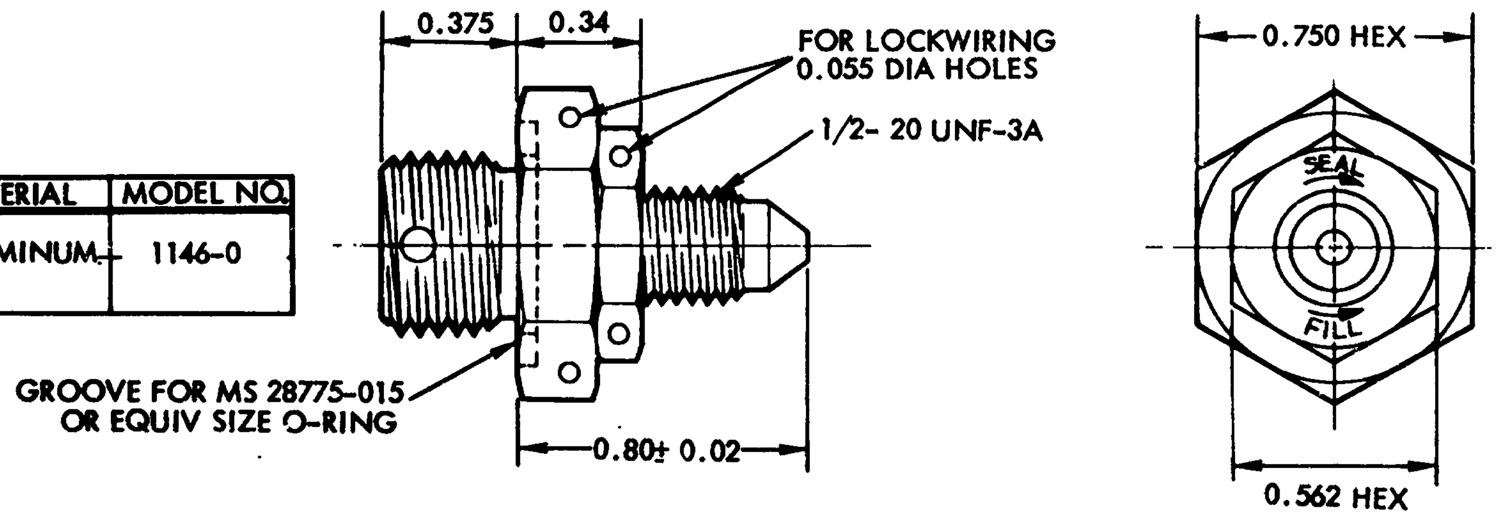


Figure 28. Prototype System Filter



MATERIAL	MODEL NO.
ALUMINUM	1146-0

Figure 29. Propellant System Fill Valve

5.2.1 Vapor Phase Ammonia Test

The first series of tests performed with the prototype system was conducted with vapor phase ammonia entering the regulator. The object of these tests was to determine the regulated pressure in the plenum tank as a function of storage tank pressure and propellant flow rate. These tests were performed in the lower range of storage pressure where the system's capability to meet the maximum flow demand is most critical. The results of these tests are shown in Figure 30.

The design specification for feed pressure control, as outlined in the program work statement, is $\pm$ 10 percent. Thus, at a nominal operating pressure of 20 psia, it would represent a lower regulated pressure level of 18 psia. One of the system design parameters is that it be capable of maintaining the maximum required flow rate of 0.001 lb/sec at a minimum tank pressure of 66 psia. This is equivalent to a tank temperature of 35°F and corresponds to the case where the maximum flow demand is initiated at a tank temperature of 40°F, continues for 300 seconds, and causes the tank temperature to drop 5°F. The data indicate that the prototype system was just short of meeting this requirement. The minimum tank pressure where the maximum flow rate could be maintained at the required delivery pressure was 70 psia.

Special tests were conducted to determine if it was possible to decrease the decay in regulated pressure at high flow rates and low storage tank pressure. Independent pressure drop measurements were performed across the capillary tube-regulator orifice combination and compared to those obtained from the single tube test. These are shown in Figure 31. At a flow rate of 1×10^{-3} lb/sec and an inlet pressure of 66 psia, there is a 12 psi difference in the pressure drop data of the tube-orifice combination test and the single tube experiments. This 12 psi differential occurs in the regulator orifice and the interface cavity between the capillary tubes and the regulator orifice. This resulted in a decision to increase the diameter of the orifice and the length of the interface cavity in the flight type design to reduce this pressure drop. Preliminary tests indicated that the decay in regulated pressure below the nominal can be limited to 1 psi at the minimum tank pressure and maximum flow rate.

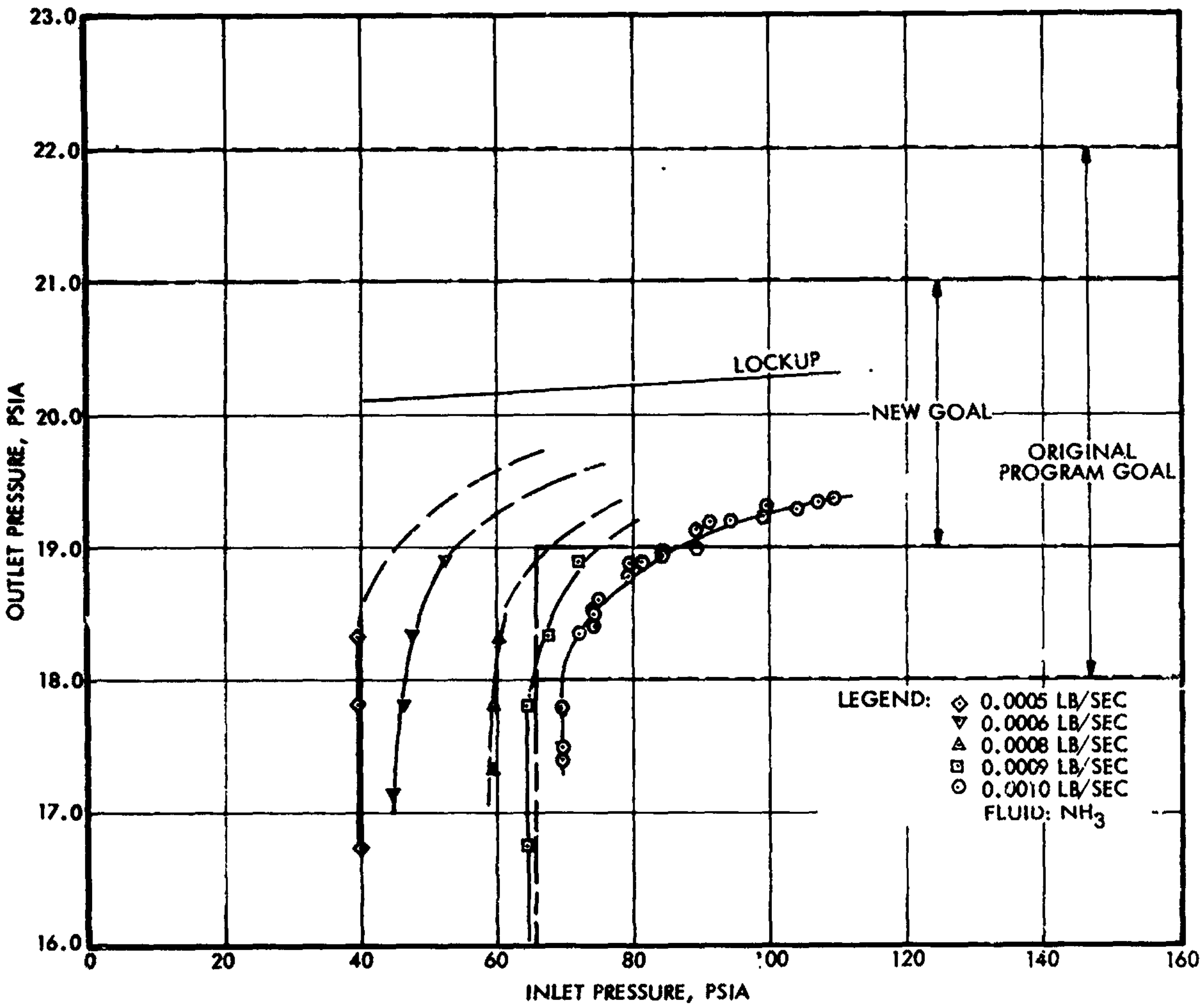


Figure 30. Low Inlet Pressure Regulation Characteristics

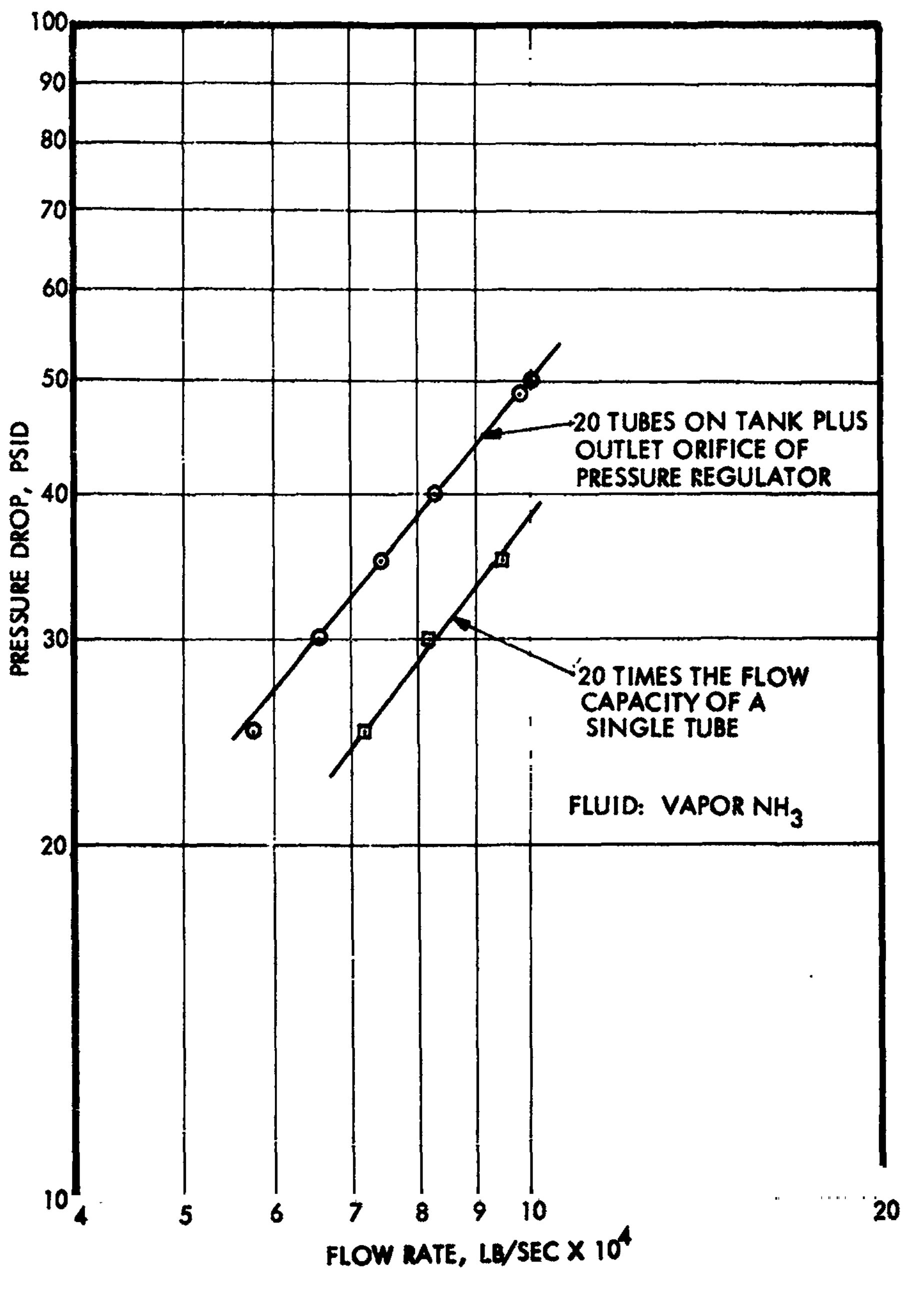


Figure 31. Capillary Tube Assembly Vapor Flow Characteristics

5.2.2 Liquid Phase Ammonia Test

The second series of tests was performed with liquid phase ammonia entering the regulator. The average pressure regulation level was only slightly affected by both tank pressure and flow rate. The average regulated pressure was 19.5 psia, except at flow rates less than 10^{-4} lb/sec, in which case the pressure remained near that of regulator lock-up (20.5 psia). The regulated pressure exhibited oscillations at flow rates in excess of 5×10^{-4} lb/sec. These pressure oscillations had a frequency of approximately 2 Hz. Amplitude increased with increasing flow and also with decreasing tank pressure. Typical pressure regulation profiles at several flow rates and tank pressures are shown in Figure 32. The maximum peak-to-peak amplitude of the pressure oscillations at a regulator inlet pressure of 120 psia was 1.0 psi, while at 66 psia the amplitude was 2.0 psi. The mean regulated pressure, along with the regulated pressure band, is shown in Figure 33 for various flow rates and tank pressures.

The pressure oscillations with liquid entering the regulator are the result of two factors. One is the presence of liquid in the capillary tubes. The effect of this liquid is to cause a pressure rise in the downstream plenum after regulator lock-up. The pressure rise resulting from vaporization of residual liquid in the capillary tubes at regulator lock-up was 0.5 psi. This was the maximum value observed during the entire test series and is within the range predicted analytically. The other factor producing the oscillations in the regulated pressure is inertia in the regulator poppet. This effect can be seen from the nature of the pressure oscillations. The oscillations are maximum at the highest flow rates and lowest tank pressures. Under these conditions, the regulator poppet has maximum movement in order to maintain the flow rate. The poppet travel necessary to maintain flow rate was reduced in the flight-type regulator by decreasing the pressure drop as previously mentioned. This, therefore, reduced regulator inertial effects.

Two long duration tests were conducted with liquid phase ammonia entering the regulator. The first was for a duration of 150 seconds, initiated at a tank temperature of 67°F. The second was for a duration

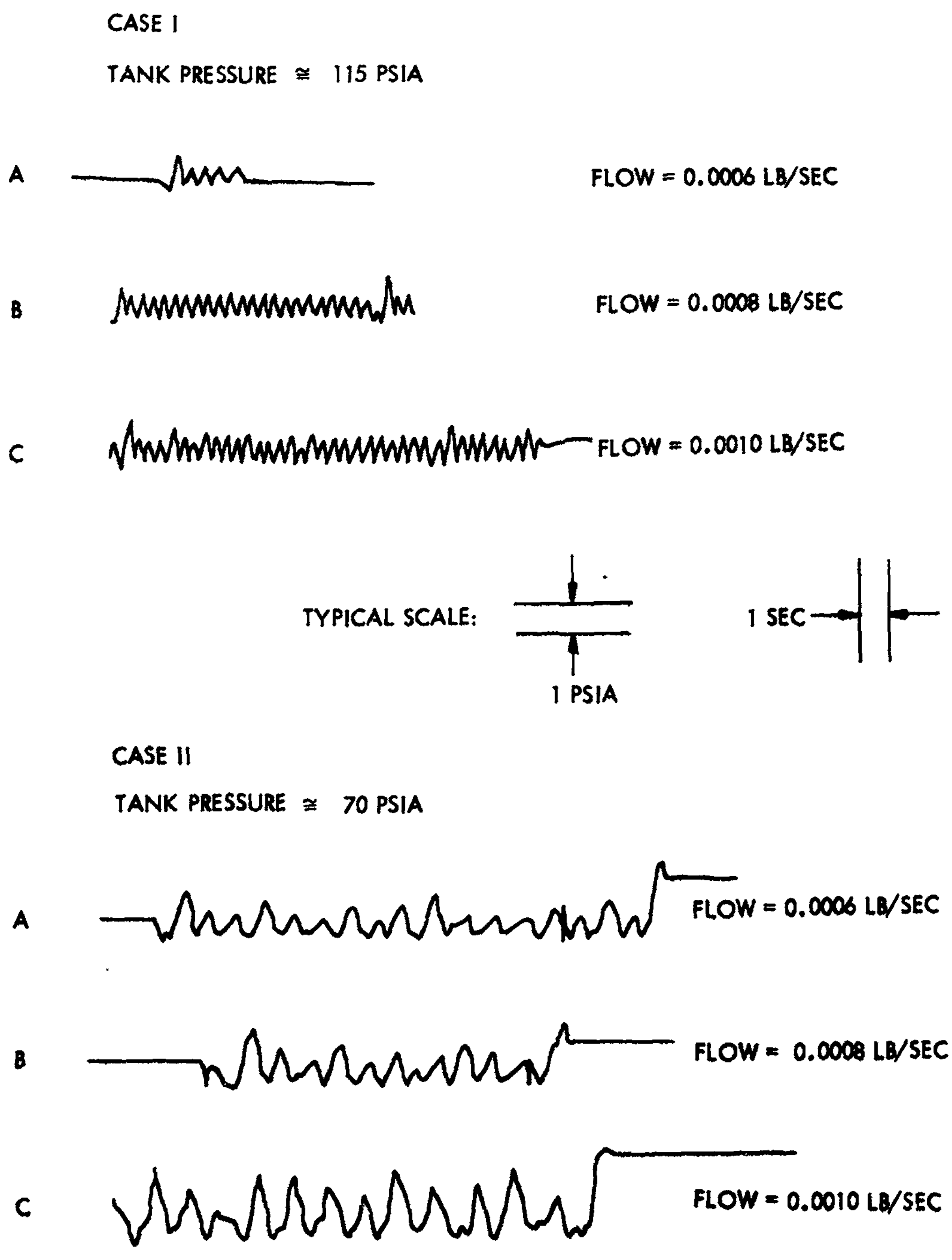


Figure 32. Regulation Characteristics with Liquid Phase Ammonia

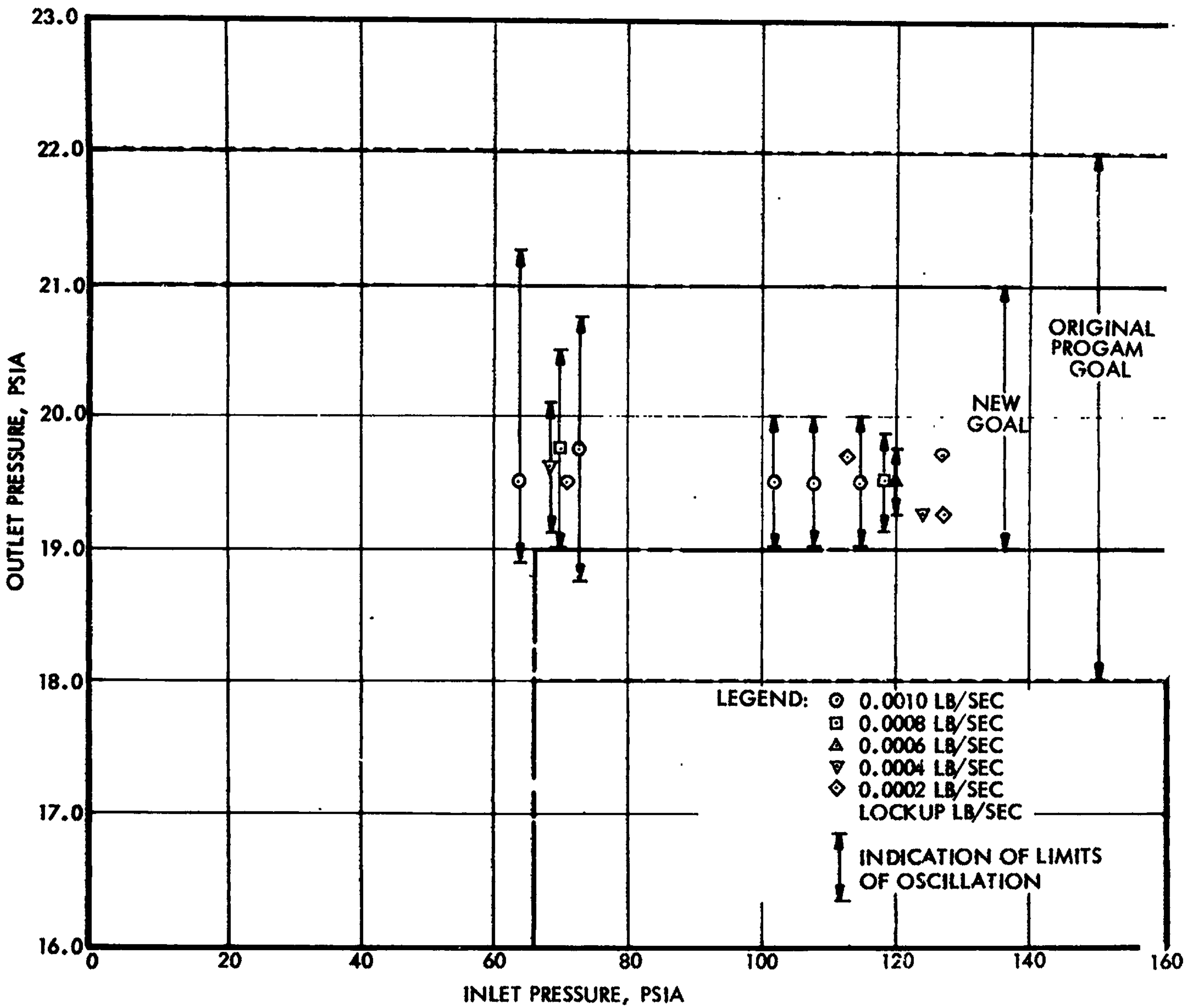


Figure 33. Liquid Phase Ammonia Pressure Control Limits

of 300 seconds, initiated at a tank temperature of 61°F. Flow rate for each case was 90 percent of the 1×10^{-3} lb/sec maximum. There was no evidence of liquid ammonia leaving the capillary tubes during these runs. This was concluded from the regulation characteristics of the system and the pressure rise at flow termination. Pressure rise at the termination of the runs was about 0.5 psi above the lockup pressure at initiation. The average tank temperature decreased by 6°F during the first sequence, and 12°F during the second. The tank loading was only 17 percent of full capacity for these tests, and the two runs were conducted with only a brief time period between them.

5.2.3 Test Conclusions

The pressure regulation characteristics exhibited by the prototype system were within the original program design goal of 20 ± 2 psia. With the exception of minor deviations, the tests demonstrated that the system has the capability of regulating pressure to within a range of $\pm$ 1.0 psi for either vapor or liquid phase ammonia entering the regulator. With minor modifications to the flight-type regulator, the deliverable feed system was expected to have this capability. A 300 second duration test with liquid withdrawal from the tank was performed with a flow rate of 9×10^{-4} lb/sec. There was no indication of liquid ammonia emerging from the capillary tubes.

Because of the excellent performance of the prototype system, the design goal of the flight-type system pressure band was changed to $\pm$ 1 psi. This control limit represents a pressure regulation band of ± 5 percent at a nominal delivered pressure of 20 psia.

6. FLIGHT-TYPE FEED SYSTEM

6.1 FLIGHT-TYPE SYSTEM ASSEMBLY

The flight-type feed system closely resembled the previous described prototype system. Minor modifications were incorporated in the pressure regulator, propellant tank and the capillary tube assembly designs. These are discussed in subsequent paragraphs. A schematic of the feed system is shown in Figure 34. The individual components are identified in Table 3.

The feed system components were assembled onto a support frame which was suspended at its center line by a pair of bearings attached to a holding frame. One of the bearing shafts was geared to an electric motor drive which could be remotely operated to rotate the propellant storage tank and allow either vapor or liquid ammonia to enter the pressure regulator. The outlet line from the plenum tank extended through the center of a bearing shaft and terminated at a bulkhead fitting located on the base frame. To allow for rotation of the feed system support frame, a flexible stainless steel line was used to extend the feed line from the center of the bearing shaft to the bulkhead fitting. The assembled flight-type feed system is shown in Figures 35 and 36.

6.1.1 Propellant Storage Tank

The propellant tank for the flight-type feed system was fabricated from tank halves identical to the ones used on the prototype system. The end boss design was changed, however, to permit a full penetration weld and to facilitate internal tank cleaning and inspection. No change was made in the fabrication procedure. The end bosses were welded to the tank halves and the welds X-rayed. The tank halves were then joined by a girth weld, which was also X-rayed. The tank was next solution-treated and aged to T6 condition. Dye penetrant inspection was performed after heat treating. Finally, the tank was proof tested at 320 psig for 10 minutes and then cleaned to TRW Specification PR2-2, Level 1.

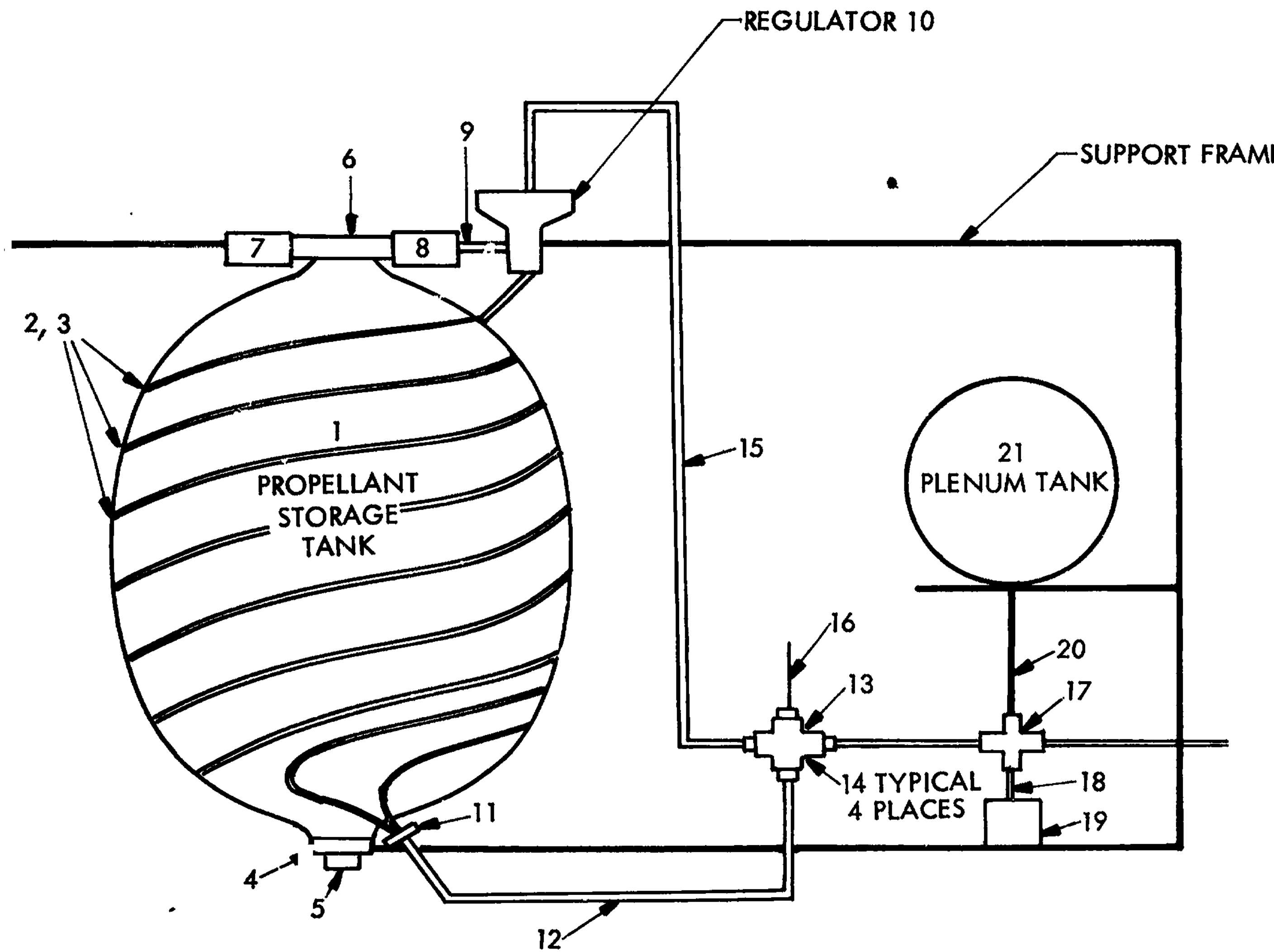


Figure 34. Demoustration Propellant System Schematic

Figure 35. Demonstration Feed System, Back View

Figure 36. Demonstration Feed System, Front View

TABLE 3. COMPONENT IDENTIFICATION

1. Propellant storage tank
2. Capillary tube assembly
3. ECCOBOND 57C solder
4. Lower mounting boss and fill valve adapter
5. Fill valve
6. Upper mounting boss
7. Storage tank pressure transducer
8. Propellant filter
9. Regulator feed line
10. Pressure regulator
11. Capillary tube outlet adapter
12. Capillary tube - plenum connecting line
13. 1/4" female AN cross
14. 1/4" AN union
15. Regulator sense line
16. Thermocouple probe
17. Male 1/4" AN cross
18. Transducer connecting line
19. Regulated pressure transducer
20. Plenum connecting line
21. Plenum tank
22. Vapor feed line

A problem was experienced in performing the girth weld on the tank. The initial welding operation resulted in excessive buildup of weld material on the interior of the tank, as well as areas of tungsten inclusion in the weld. Rework of the various defective weld areas was not 100 percent successful. Consequently, the tank was cut apart and the weld area removed. The tank halves were then re-welded with no further problems. The rework operation removed approximately 1 inch of the cylindrical middle section of the tank. The resultant tank volume was 1600 cu. in. for the flight-type system, compared to 1780 cu. in. for the prototype tank. This is equivalent to a full tank (zero ullage) load of 33.7 of ammonia at 100°F.

A layout of the propellant storage tank is shown in Figure 37. The tank specifications are:

Medium	Anhydrous ammonia
Volume	1600 in^3
Weight	7.8 lb
Tank Material	6061-T6 Aluminum
Weld Material	4043 Aluminum
Operating pressure	212 psia maximum
Proof pressure	320 psig
Burst pressure	465 psia minimum
Temperature range	20° to 100°F

6.1.2 Plenum Tank

A layout of the plenum tank is shown in Figure 38. The specifications for this tank are:

Medium	Vapor phase ammonia
Volume	110 in^3
Weight	0.38 lb
Tank Material	3003 aluminum
Operating pressure	50 psia maximum
Proof pressure	75 psig
Burst pressure	110 psig minimum
Temperature range	20°F to 100°F

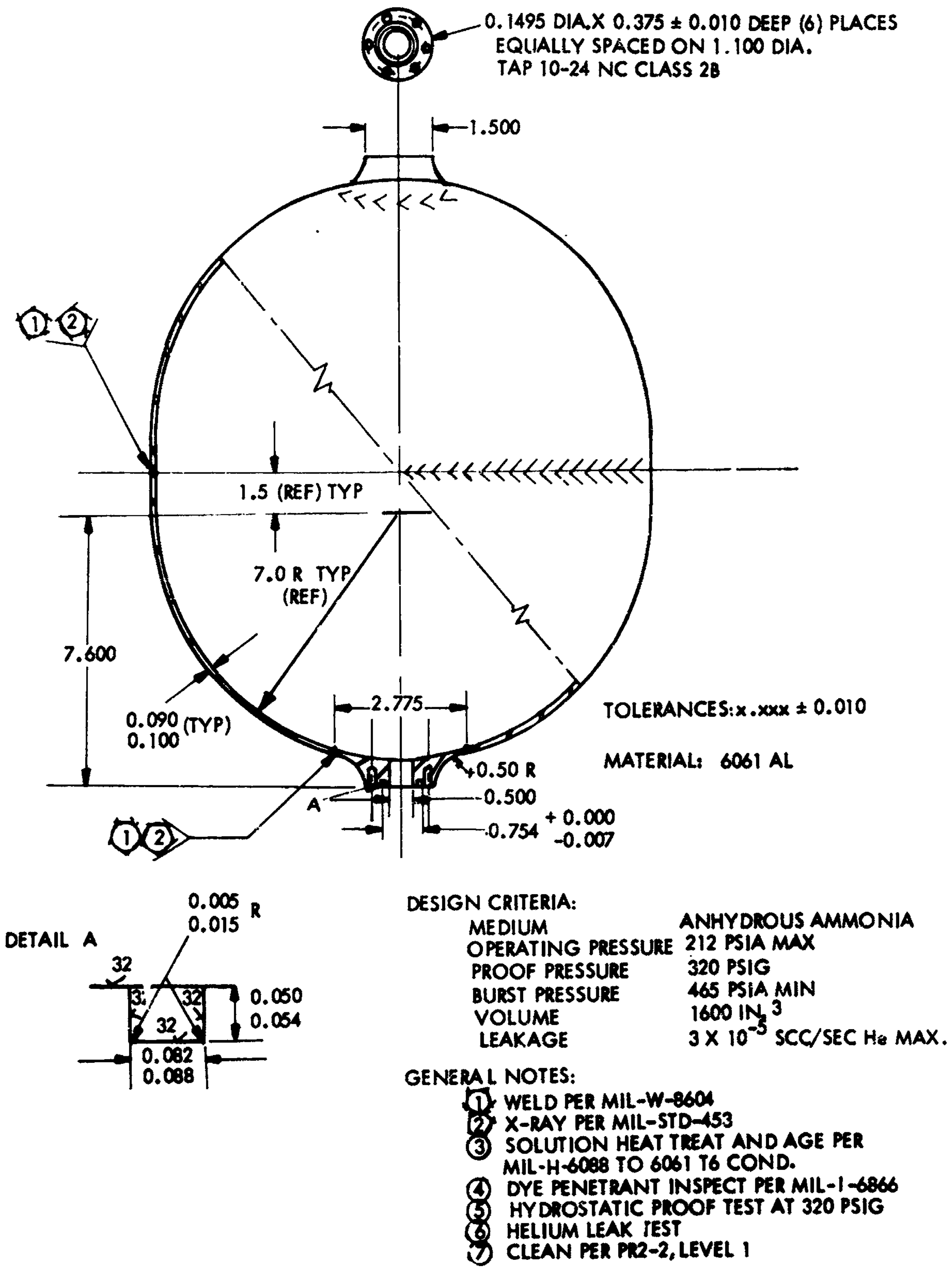
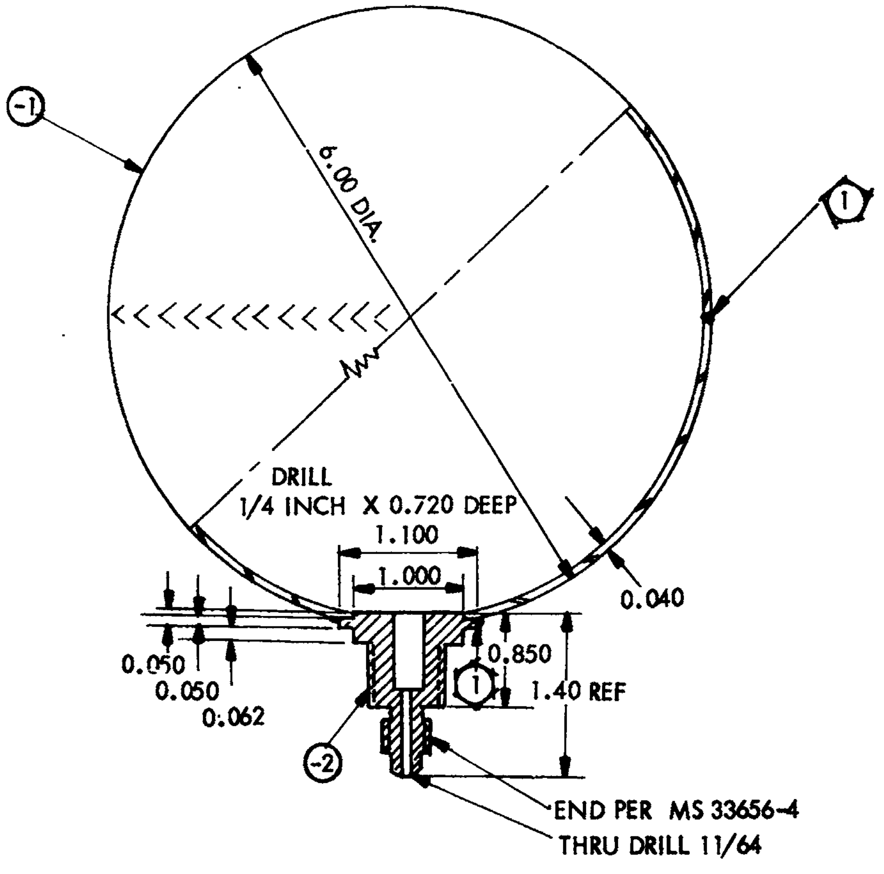


Figure 37. Demonstration System Propellant Tank Layout



DESIGN CRITERIA:

MEDIUM	VAPOR PHASE AMMONIA
OPERATING PRESSURE	50 PSIA MAX
PROOF PRESSURE	75 PSIA
BURST PRESSURE	110 PSIA MIN
VOLUME	110 IN^3
LEAKAGE	3×10^{-5} SCC/SEC He MAX.

GENERAL NOTES:

1 WELD PER MIL-W-8604

MATERIAL:

-1 3003-0AL

-2 6061-T6AL

Figure 38. Demonstration System Plenum Tank Layout

The spherical plenum tank was purchased from the Industrial Vessel Division of Chicago Float Works. The tank was delivered in the annealed condition. The strength characteristics of the non-hardened 3003 alloy are sufficient to meet the requirements for this application.

6.1.3 Capillary Tubes

The capillary tubes used in the feed system have an internal diameter of 0.017 inch and an external diameter of 0.033 inch. They are each 36 inches in length and are made of type 321 stainless steel. A total of 20 tubes are used in parallel. These dimensions are identical to the tubes bonded to the prototype tank. The fittings at each end of the tube bundle were redesigned for the flight-type system. These are shown in Figure 39 for the capillary-regulator interface and Figures 40a and 40b for the capillary-plenum time interface. A reliable, leak tight assembly is obtained in each case by individually brazing each of the capillary tubes into the headers with Nicrobraze L. Final seal at each interface is by an Buna N "O"-ring.

A final flow calibration of the tube assembly indicated no obstructions or restrictions in any of the tubes. The measured pressure drop across the tube assembly as a function of ammonia flow rate is shown in Figure 41. The tube assembly was cleaned to TRW Specification PR2-2, Level 0.

The placement of the capillary tubes on the storage tank is shown in Figures 42 and 43. The capillary tubes were bonded to the tank surface with ECCOBOND solder 57C. The capillary tubes and the areas of the storage tank on which the epoxy was applied were cleaned with an ammonium biflouride-nitric acid solution.

6.1.4 Propellant Filter

A 15 micron absolute filter is connected directly to the outlet of the propellant tank. The filter, P/N 15241-654, which is an in-line, screen type filter made entirely of noncorrosive steel, is manufactured by Wintec Corporation. The filter is shown in Figure 44. The specifications for it are:

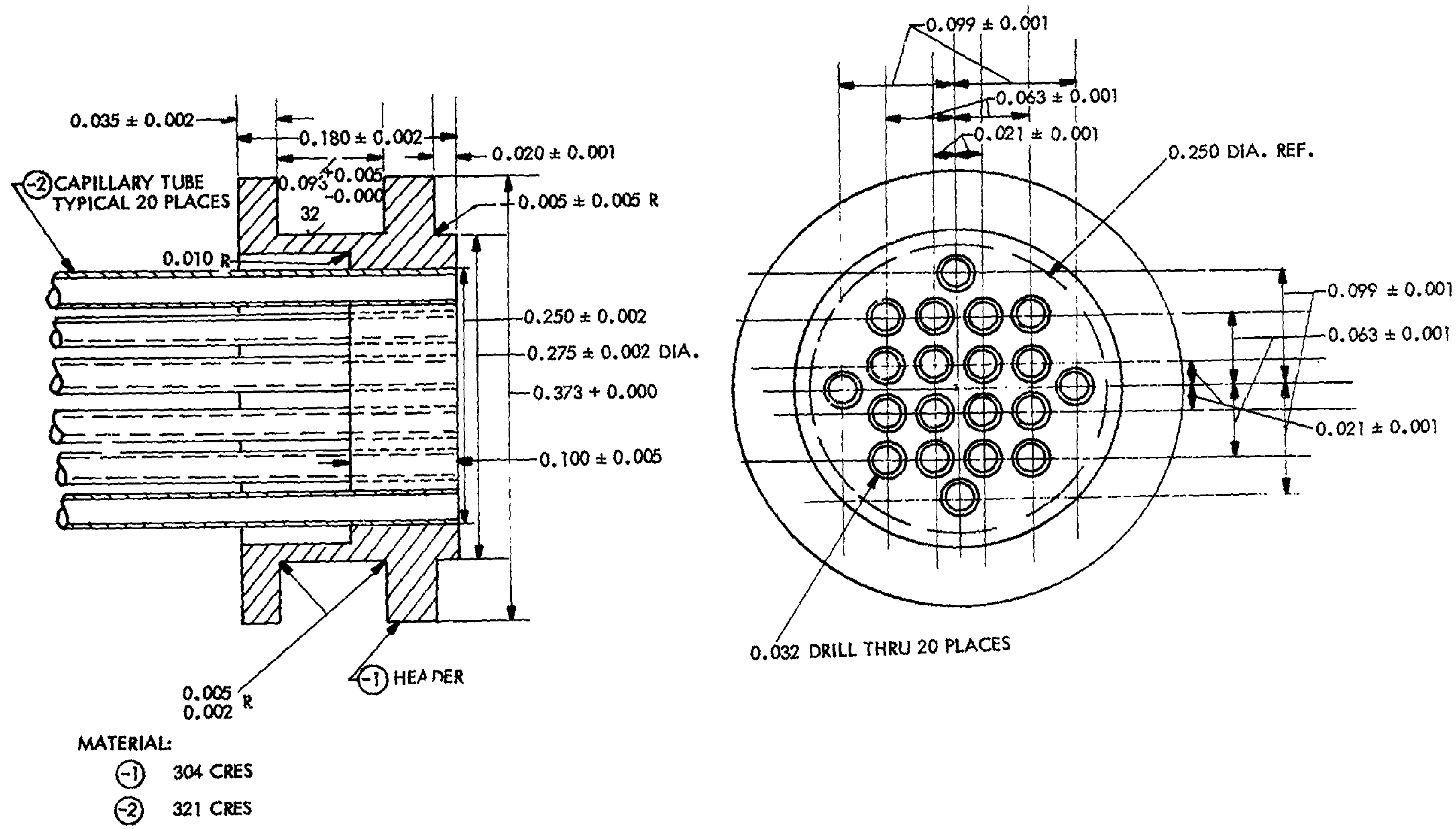


Figure 39. Capillary Tube Inlet Header

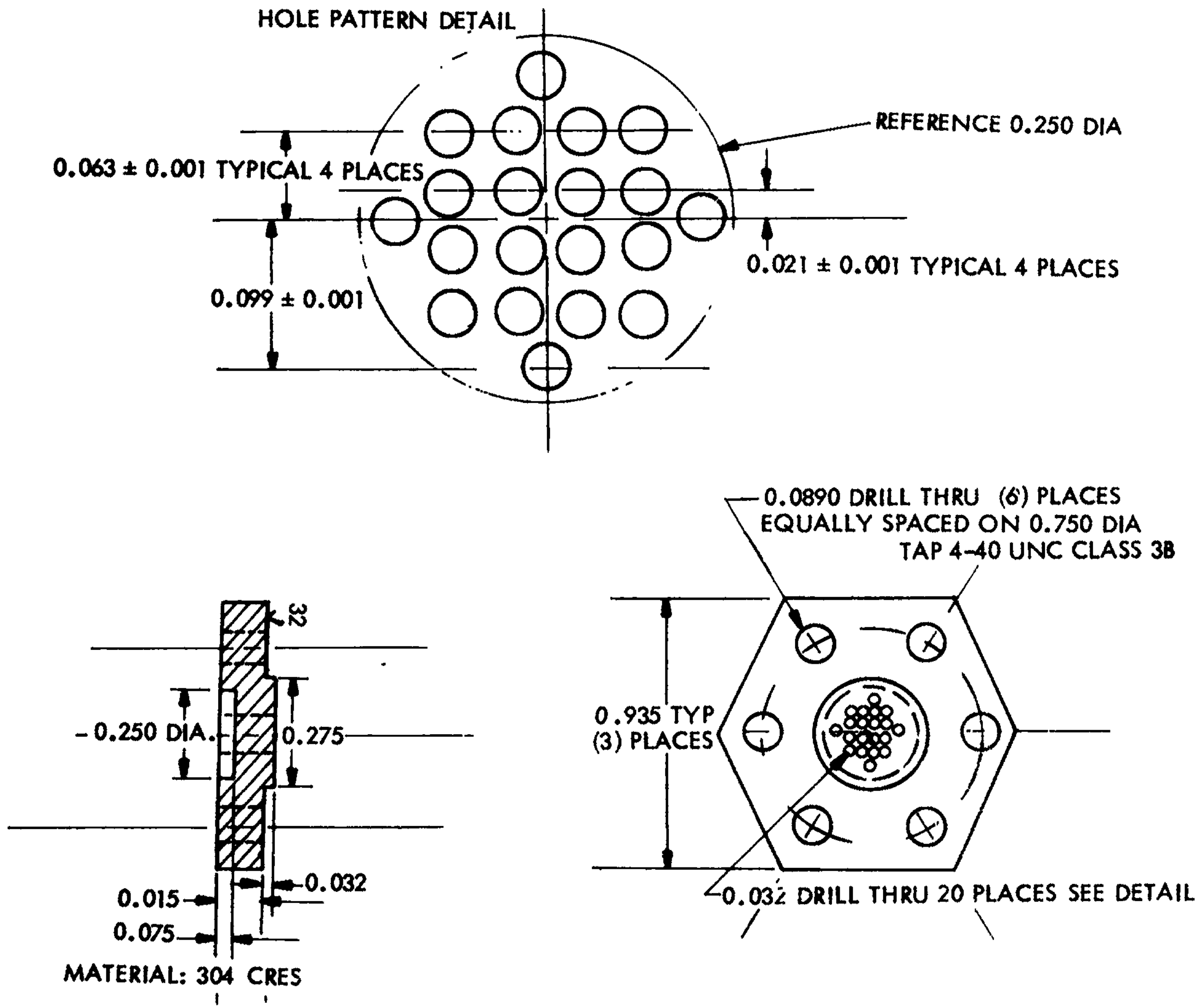


Figure 40a. Capillary Tube Exhaust Header

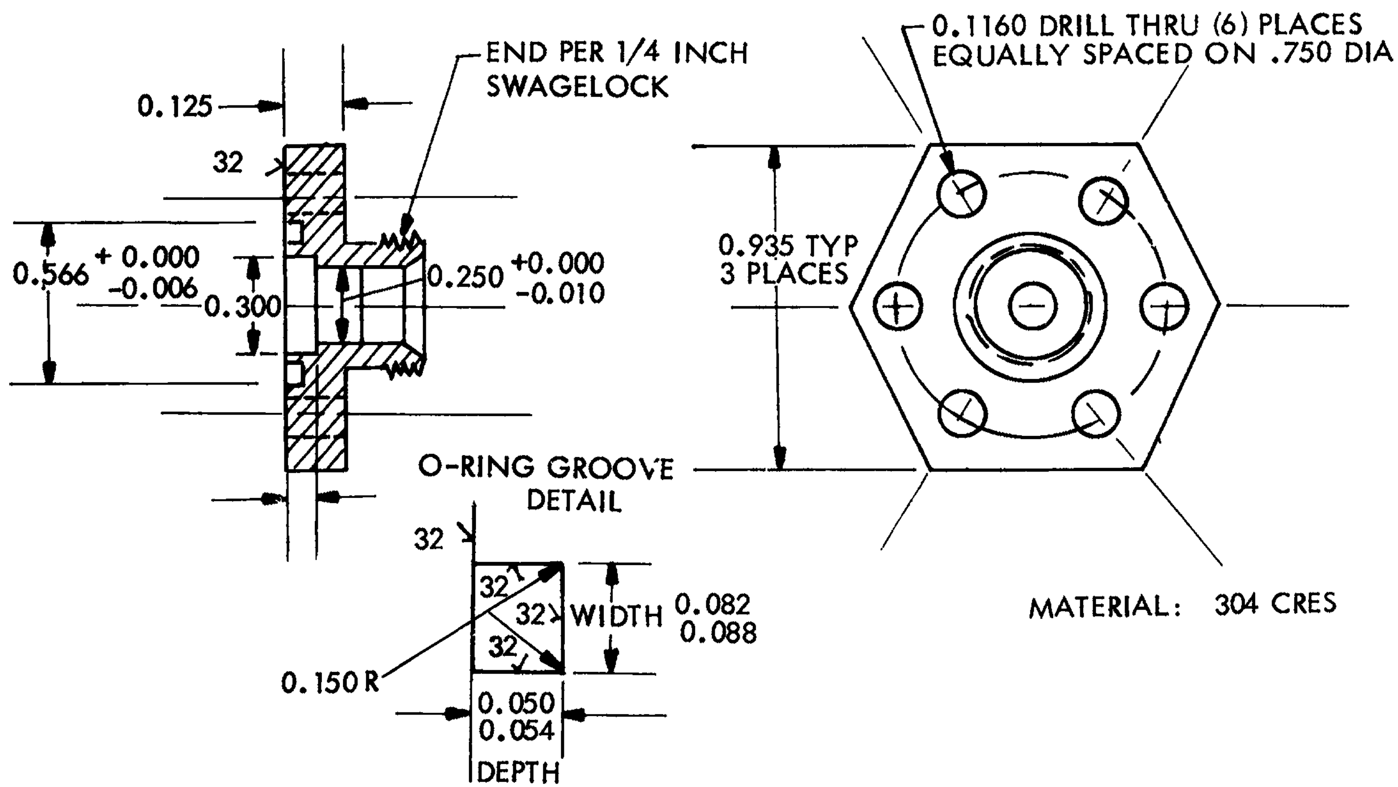


Figure 40b. Exhaust Header Mating Flange

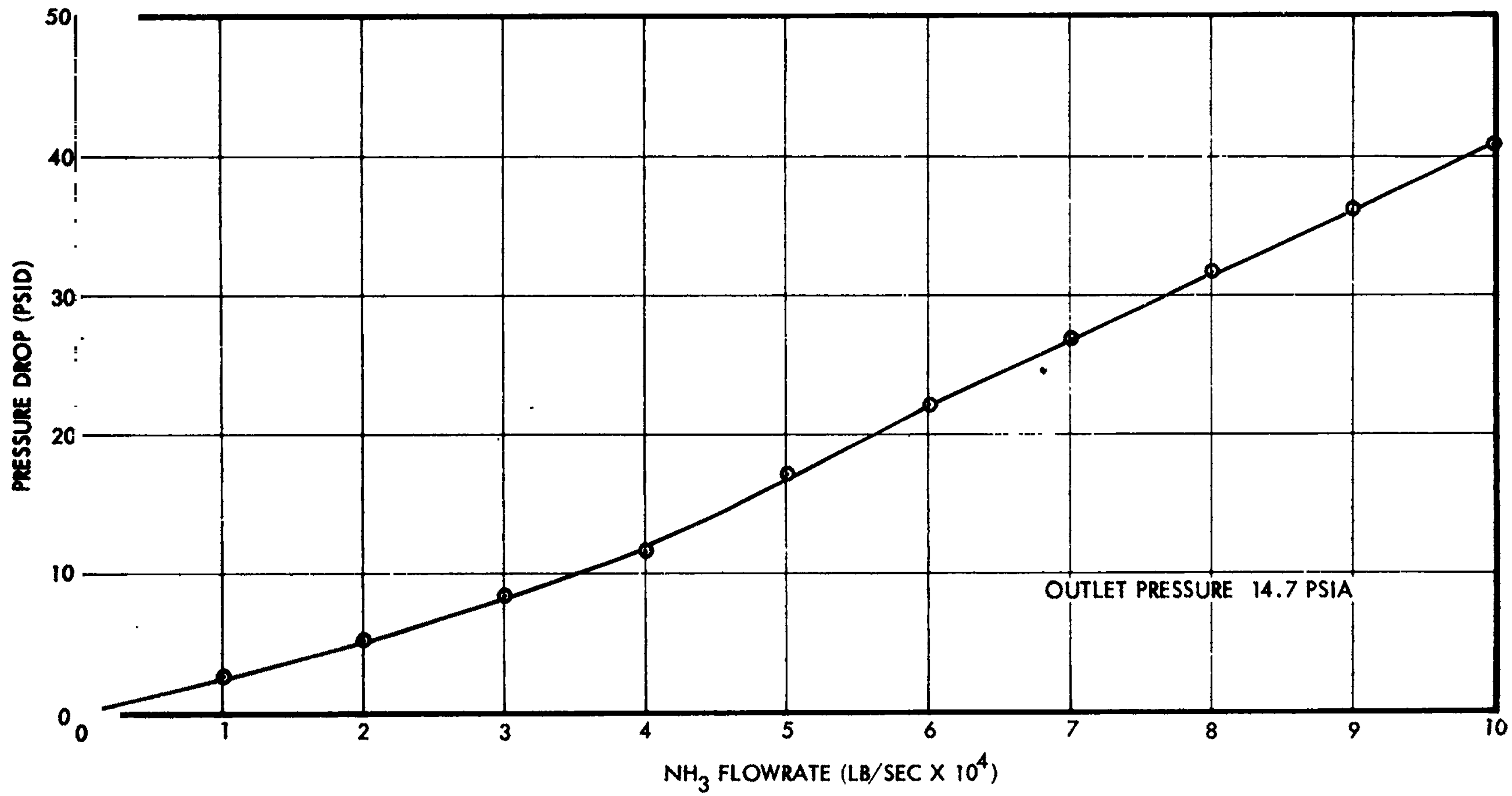


Figure 41. Capillary Tube Assembly Pressure Drop

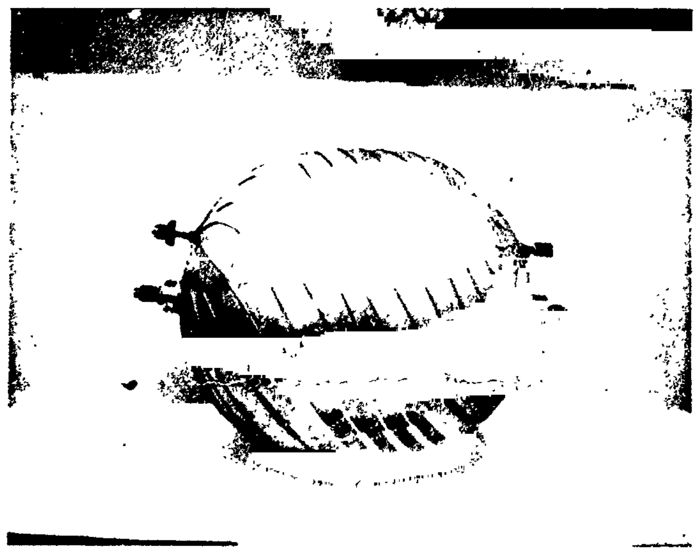


Figure 42. Tank and Flow Tubes, Side View

Figure 43. Tank and Flow Tubes, End View

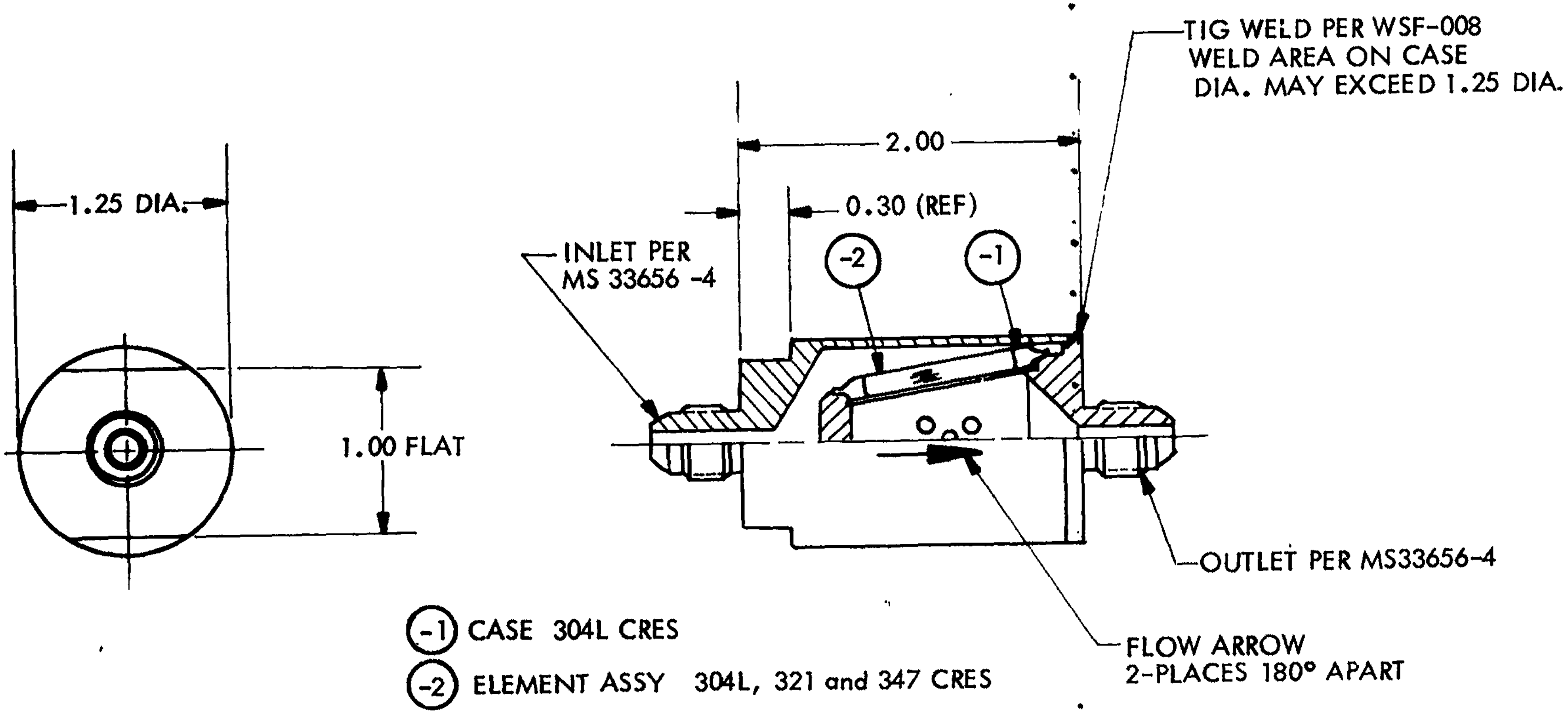


Figure 44. Demonstration System Filter

Medium	Anhydrous ammonia
Rating	15 micron absolute
Effective screen area	8 in^2 minimum
Operating pressure	220 psig
Proof pressure	440 psig
Burst pressure	880 psig minimum
Element collapse pressure	250 psid minimum in flow direction
Cleanliness	PR2-2, Level 1

6.1.5 Fill Valve

The storage tank fill valve, which can also be used as the drain valve, is shown in Figure 29. It is manufactured by Pyronetics, Inc. The valve poppet has redundant seals. The primary seal is metal to metal. The secondary seal is formed with an "O"-ring that seals the outer surface of the poppet and an AN-cap that seals the flow passage in the center of the poppet. The valve is operated manually with an open-end or torque wrench. The valve specifications are:

Medium	Anhydrous ammonia
Operating pressure	Up to 4000 psig
Closing torque	50 $\pm$ 2 in-lb
Leakage (primary)	1 x 10^{-5} scc/sec
Material: body	Aluminum
"O"-ring	Buna N

6.2 FLIGHT-TYPE SYSTEM TEST

The feed system was subjected to a series of tests to determine its operating characteristics at various flow rates, duty cycles and propellant pulse durations with both vapor and liquid phase ammonia leaving the storage tank. The objective of the tests was to determine the regulation capability and stability of the feed system over the ranges of operational duty cycles and environmental temperatures. The tests were conducted in a vacuum environment within a system temperature range of 20°F to 100°F.

6.2.1 Test System

The components of the flight-type feed system are described in detail in Section 6.1 of this report. The feed system was integrated into a demonstration test system which, in addition to the system itself, included the required propellant distribution lines, flow control valves, pressure and temperature monitoring and recording equipment, valve driver and pulse command circuits, and a propellant flow meter. A schematic of the demonstration test system is shown in Figure 45.

In order to evaluate operation of the demonstration system in a simulated space environment (except for the zero gravity field), the test was performed in a vacuum environment. The vacuum chamber used for these tests is a 4 foot long cylinder with dished ends. One end contains the ports through which the tank is evacuated. The other end is a hinged door with an "O"-ring seal and a 10 inch view port. The cylindrical section has three 10 inch flanged ports in which all the electrical and propellant feed-throughs were located. Vacuum was maintained by a Stokes, Model 149H-10, 80 CFM, mechanical pump. The pump had the capability of maintaining a vacuum of less than 10 microns in the chamber with no propellant flow. However, with ammonia discharged into the chamber at the maximum flow rate of 1×10^{-3} lb/sec, the pressure in the vacuum chamber increased to 0.2 psia. Chamber pressure was monitored with a dual channel thermocouple gauge and a differential pressure gauge.

Feed system temperature control was provided by two 500-watt flood lights for the high temperature tests, and by liquid nitrogen cryopanels around the propellant tank for the low temperature tests.

6.2.2 Test Procedure

Following the assembly of the flight-type feed system, preliminary checkout was performed with the storage tank charged to only a fractional amount of its full capacity. The proper operation of the system was thereby verified prior to the demonstration test.

The system demonstration test was conducted over a four week period. During this time, system evaluation tests were performed to investigate operating characteristics under four separate modes of operation. The tank contained maximum propellant charge at the start of the demonstration test.

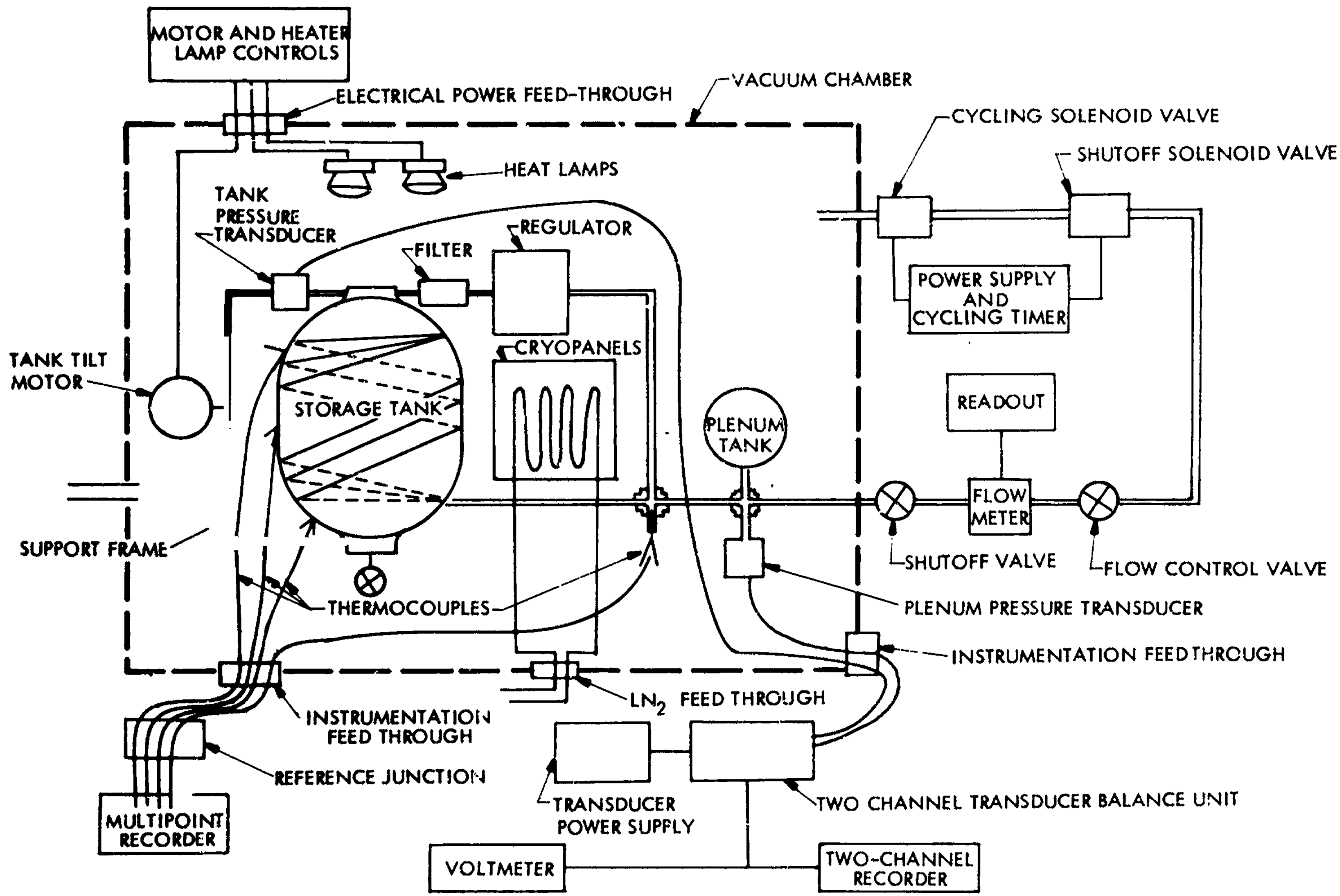


Figure 45. Demonstration System Test Schematic

1. System Operating Characteristics Under High Flow Demand
   Flow rate: 1×10^{-3} lb/sec
   Duty cycle: steady state for 300 seconds
   Propellant Phase: vapor and liquid withdrawal
   Propellant Temperature: 40°F and 100°F
2. System Operating Characteristics at Moderate Flow Demands for Long Time Period
   Flow rate: 3×10^{-5} lb/sec
   Duty cycle: steady state for 8 hours
   Propellant Phase: vapor and liquid withdrawal
   Propellant Temperature: 70°F
3. System Operating Characteristics at High Pulse Mode Duty Cycle
   Flow rate: 1×10^{-3} lb/sec
   Duty cycle: 3% for 2 hours
   Propellant Phase: vapor and liquid withdrawal
   Temperature: 40°F and 100°F
4. System Operating Characteristics During Coast Mode
   Flow rate: 5×10^{-4} lb/sec
   Duty cycle: 0.2% for two weeks
   Propellant Phase: vapor and liquid withdrawal
   Temperature: 70°F

The demonstration test consisted of performing the first three modes, the coast mode and then a repeat of the first three.

6.3 FLIGHT-TYPE SYSTEM TEST RESULTS

6.3.1 Preliminary Tests

The propellant storage tank was initially filled with approximately 5 pounds of ammonia. Preliminary check-out of the demonstration test system was then conducted with vapor and liquid phase ammonia withdrawal from the storage tank. After initial exposure to ammonia, the flight-type regulator exhibited a downward shift of its pressure regulation band of approximately 0.5 psi. This regulation level change is caused by a slight swelling of the elastomeric seat, and occurs only after the initial contact of the seat with ammonia. The regulator was re-adjusted to the original regulation set point. Test results for the preliminary system flow tests are shown in Figure 46. The regulator lockup pressure was set at 20.4 psia. Regulation level at the maximum flow rate (1×10^{-3} lb/sec) with vapor withdrawal was approximately 1.0 psi below the lockup pressure. The regulated pressure starts to drop off at lower propellant tank pressures until the regulator is unable to maintain regulation at the maximum flow rate for tank pressures below 62 psia. This value corresponds to a saturated ammonia temperature of 34°F, and is a significant improvement over the 70 psia limitation exhibited by the prototype system. With liquid ammonia entering the pressure regulator, the flight-type system exhibited its characteristic oscillatory behavior at flow rates in excess of 4×10^{-4} lb/sec. The oscillations were of lower amplitude than those of the prototype regulator at comparable flow rates. The amplitude of the oscillations increased with increasing flow rate and also with decreasing tank pressure. The reason for these oscillations has been previously discussed in Section 5.3.2.

At the conclusion of the preliminary flow tests, the storage tank was drained of all residual ammonia. Moisture was removed from the internal volume of the system by applying a vacuum. The system was then filled with dry argon prior to filling with ammonia. Charging of the storage tank was accomplished by connecting the tank fill valve to the liquid withdrawal tube of an ammonia supply cylinder. The flow control valve was opened periodically to vent the vapor phase in the storage tank. This venting maintained the pressure in the system tank below that of the supply tank, and permitted liquid transfer due to the pressure differential. During the filling procedure, the propellant tank was tilted at a 45 degree angle by rotating the feed system within the holding frame. The filling process was terminated when liquid phase ammonia started to vent from the propellant tank. The onset of liquid flow from the storage tank was determined by the oscillatory behavior of the regulated pressure. The resultant tank charge was calculated at 32 pounds of ammonia. The calculations were based on the knowledge of tank geometry, the tilt angle, and the propellant specific weight at the temperature (approximately 50°F) existing during the filling procedure. The achieved weight had been chosen to provide a 10% tank ullage

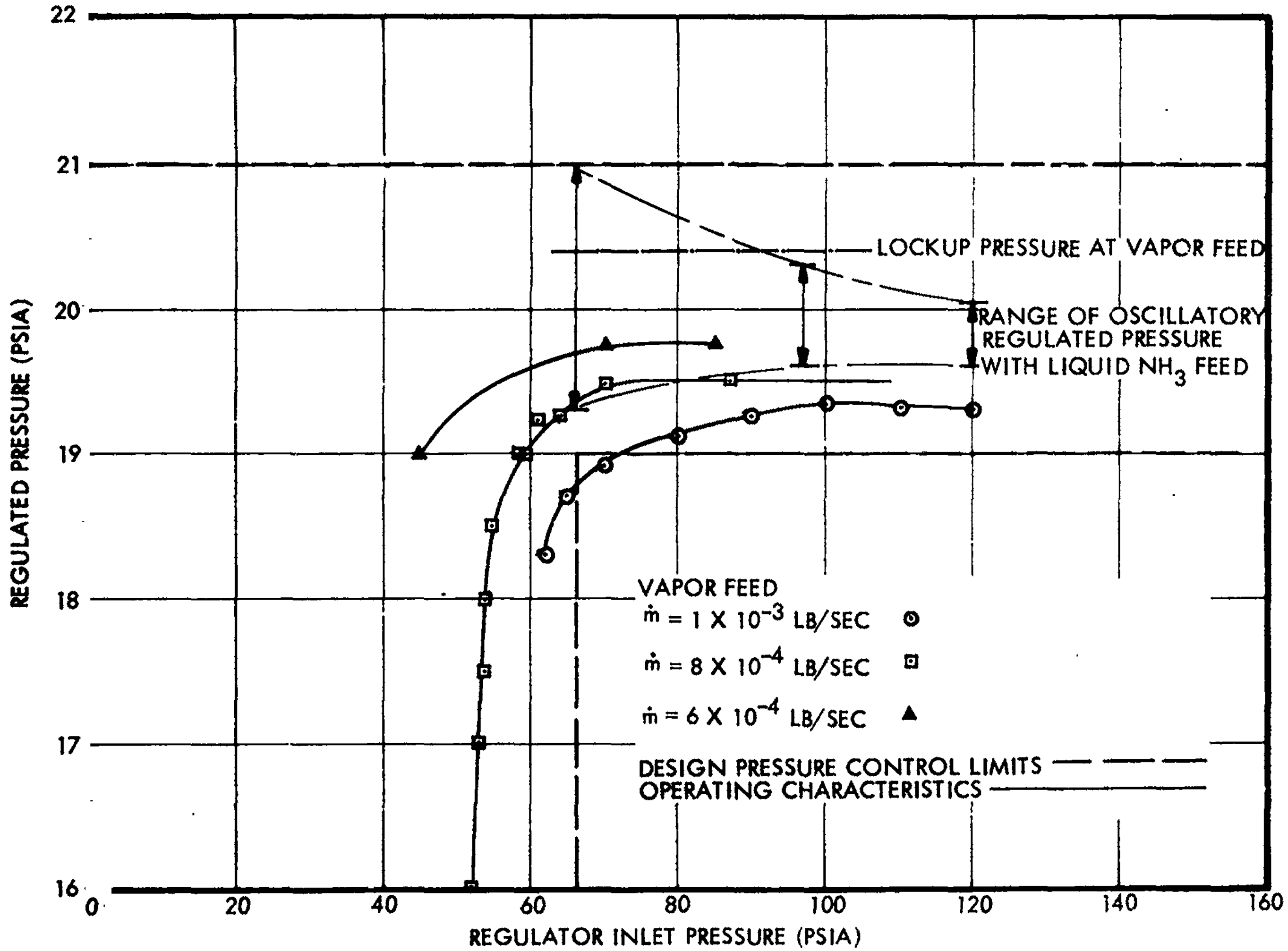


Figure 46. Steady-State Flow Regulation Characteristics, Preliminary Test Data

at the temperature existing during the filling procedure. Thus, sufficient space was available for propellant expansion when conditioned to the elevated test temperatures.

6.3.2 Test Results for System Operating Under High Flow Demand

6.3.2.1 Performance Requirement

The maximum system flow demand is 1×10^{-3} lb/sec for a period of 300 seconds. The minimum temperature at which the maximum flow rate is initiated is 40°F. The feed system is required to maintain the regulated pressure at 20 ± 2.0 psia under these conditions. However, based on the excellent regulation characteristics of the prototype system, the new design goal was established at 20 ± 1.0 psia.

6.3.2.2 Vapor Phase Withdrawal

Test runs with vapor phase ammonia supplied to the regulator were conducted for 360 second time periods, or 60 seconds longer than the maximum requirement. Test results at low temperature are shown in Figures 47 and 48 for the initial and the final tests of the demonstration test period. The system was operated in the coast mode between the initial and final test series. System performance for the two runs is identical. Regulator lockup is at 20.25 psia, the regulation level at 18.75 psia. The latter falls outside the 20 ± 1.0 psia regulation goal set for the feed system. However, it is well within the original requirement of 20 ± 2.0 psia.

Test results at high temperature are shown in Figures 49 and 50 for the initial and final performance tests. Lockup pressure and regulation level are well within the design goal limits. The large drop in the measured tank pressure, as shown in Figure 49, is caused by thermal gradients existing within the propellant tank. These thermal gradients are caused during heating of the propellant within the storage tank.

6.3.2.3 Liquid Phase Withdrawal

Test runs with liquid phase ammonia supplied to the regulator were similarly conducted for 360 seconds. Test results at low temperature are shown in Figures 51 and 52 for the tests before and after the coast mode operation. Test runs were started with the propellant at 39°F. In each

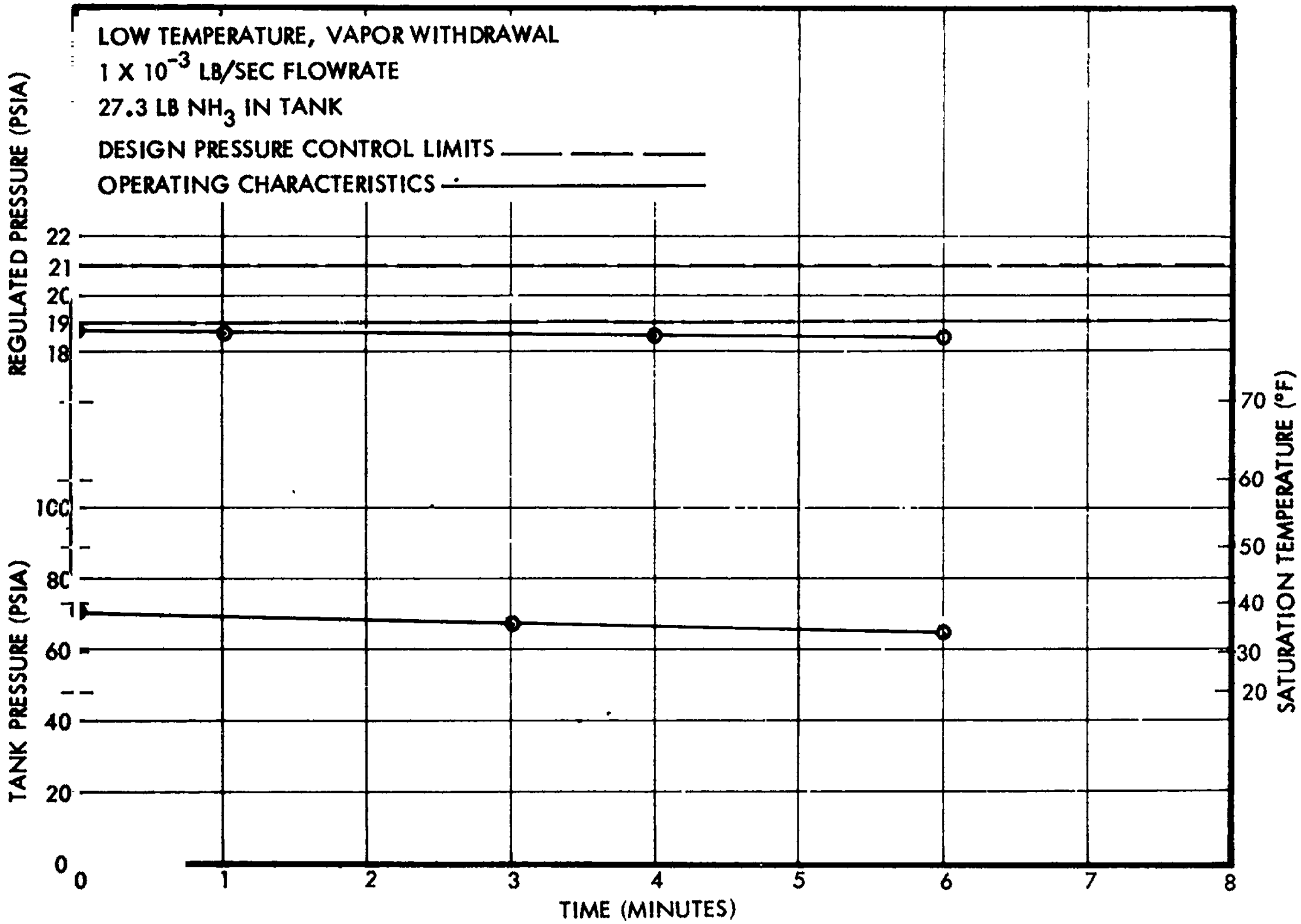


Figure 47. Low Temperature, Vapor Phase, Steady-State, Maximum Flow Regulation Characteristics, Initial Series

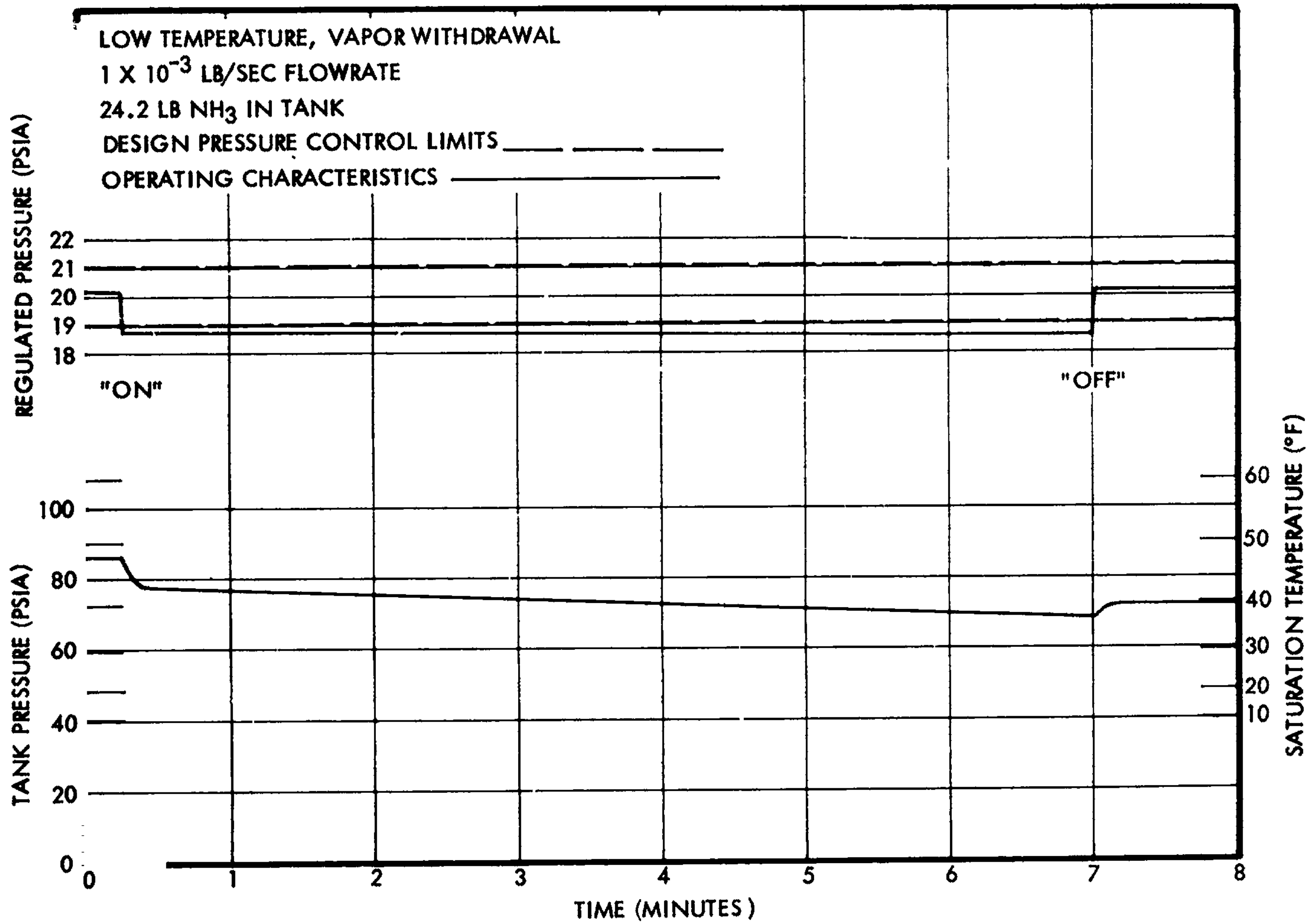


Figure 48. Low Temperature, Vapor Phase, Steady-State, Maximum Flow Regulation Characteristics, Final Series

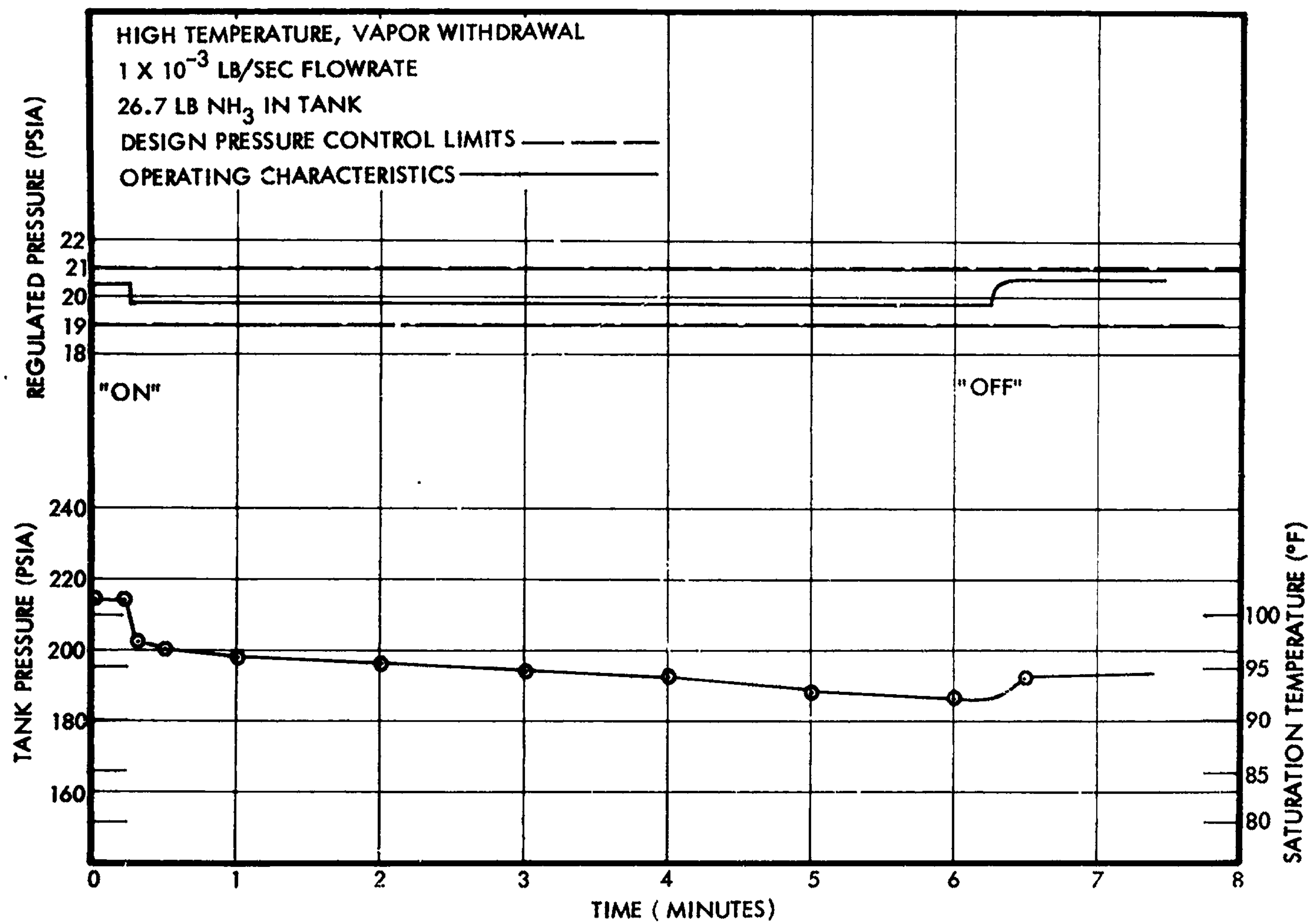


Figure 49. High Temperature, Vapor Phase, Steady-State Maximum Flow Regulation Characteristics, Initial Series

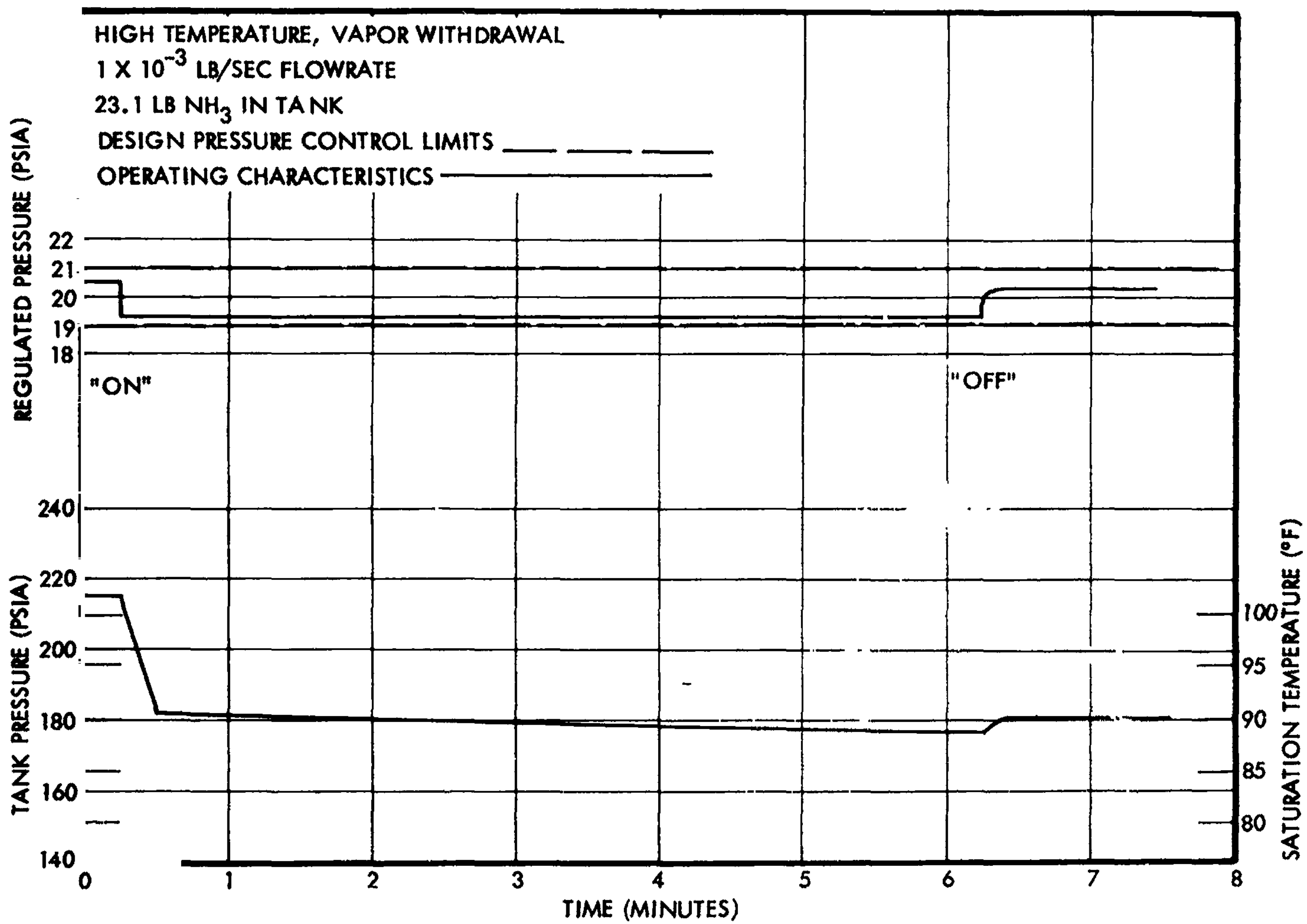
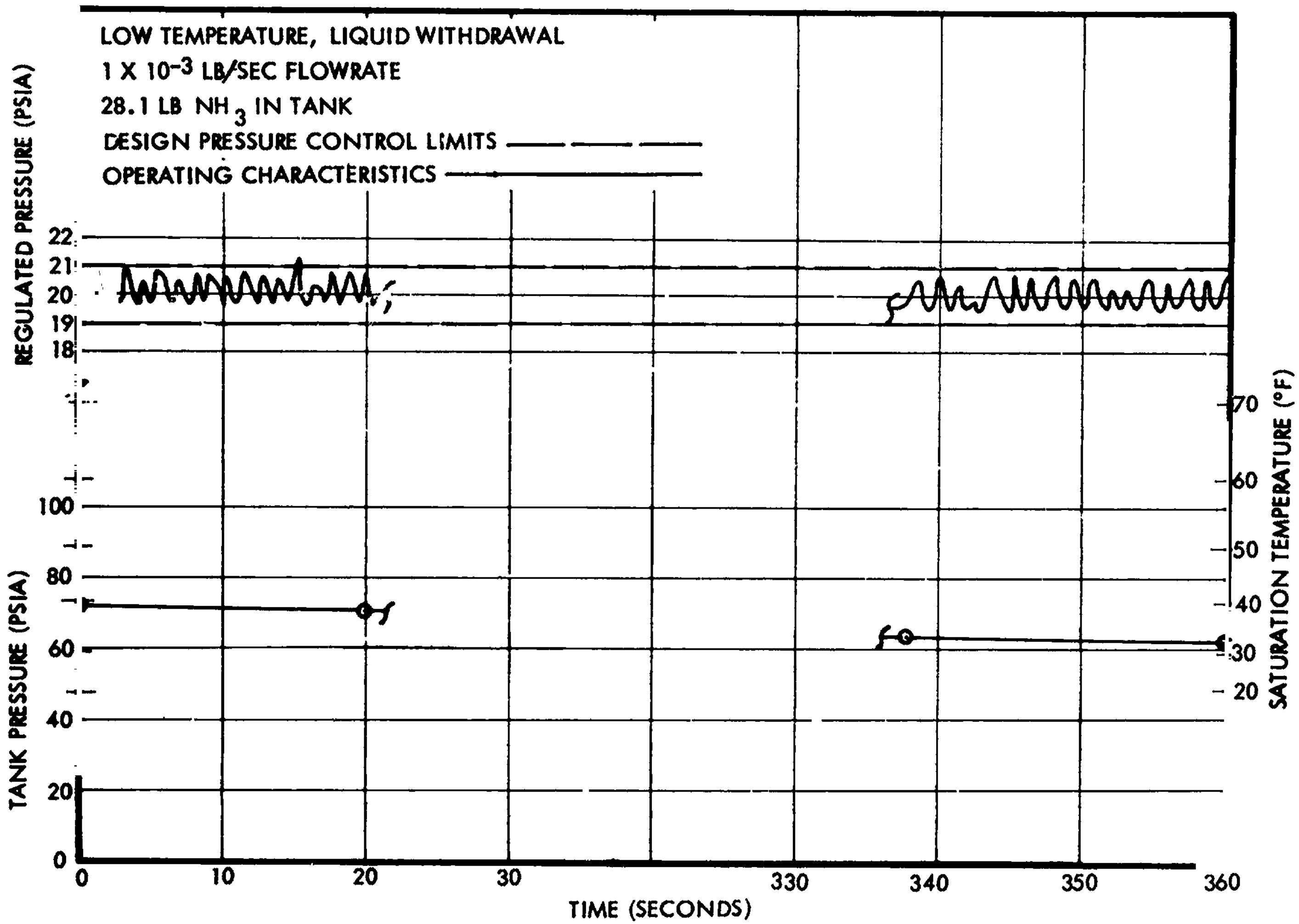


Figure 50. High Temperature, Vapor Phase, Steady-State Maximum Fl.w Regulation Characteristics, Final Series



SATURATION TEMPERATURE (°F)

Figure 51. Low Temperature, Liquid Phase, Steady-State Maximum Flow Regulation Characteristics, Init'al Series

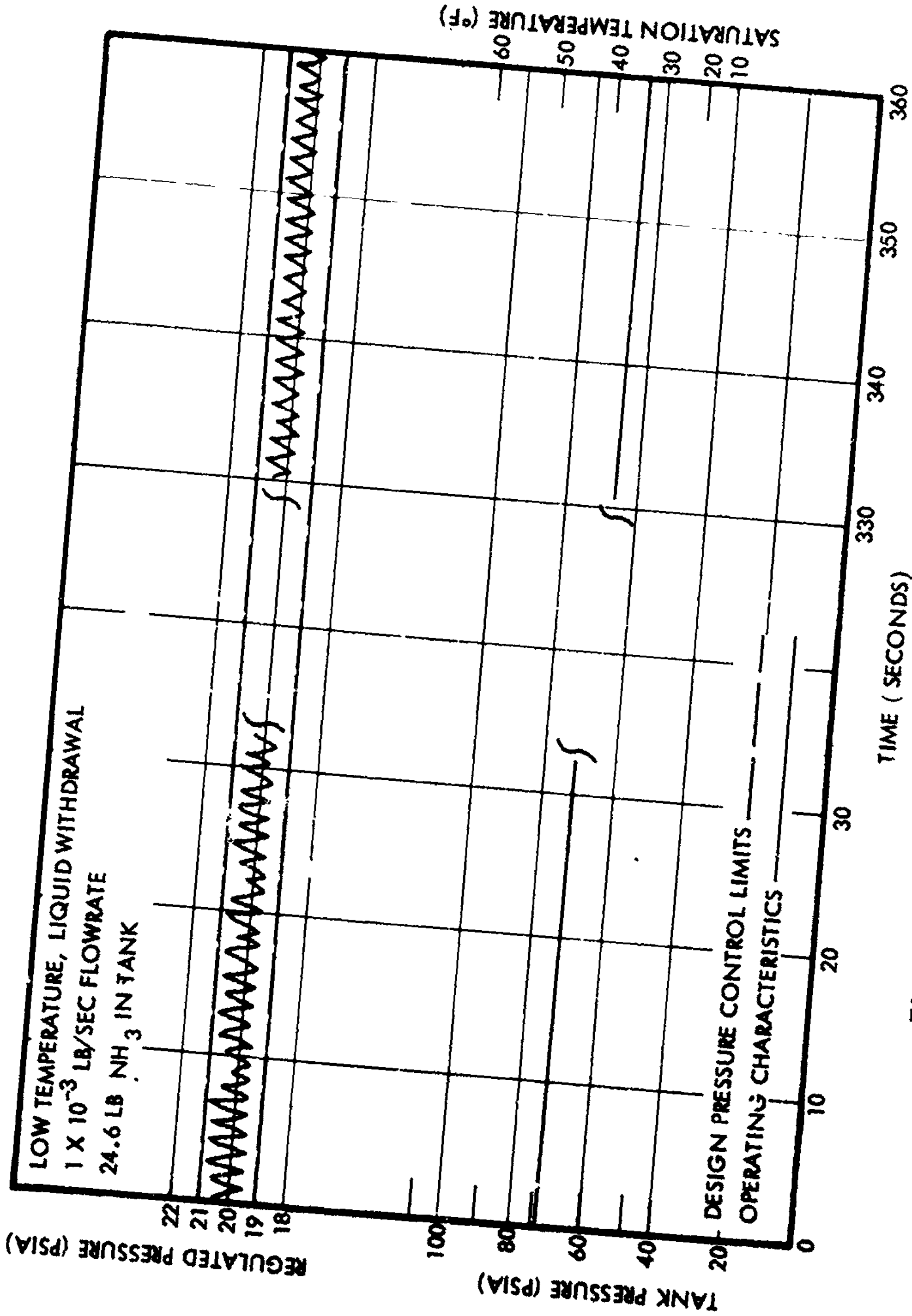


Figure 52. Low Temperature, Liquid Phase, Steady-State Maximum Flow Regulation Characteristics, Final Series

case, the regulated pressure oscillated at an approximate frequency of 1 Hz and peak-to-peak magnitude of 1.5 psia. The amplitude of the pressure oscillations did not exceed the design goal limits. At the high propellant temperature (100°F), the regulated pressure oscillations were reduced to 0.25 psi peak-to-peak. These test results are shown in Figures 53 and 54 for the tests before and after the coast mode operation. Under no conditions was there any indication of liquid ammonia emerging from the capillary tubes. The average amount of propellant in the storage tank was approximately 27.0 lb during the initial high flow tests and 23.5 lb during the final tests, corresponding to 77% and 68% of full tank capacity.

6.3.3 Test Results for System Operating at Moderate Flow Demands for Long Time Periods

6.3.3.1 Performance Requirements

The operating requirement for the system is that it must be capable of maintaining a continuous flow rate of 3×10^{-5} lb/sec. The minimum temperature at which this mode will be initiated is 25°F.

6.3.3.2 Vapor Withdrawal

The initial test at 3×10^{-5} lb/sec flow rate was initiated with the propellant temperature at 62°F and continued for 8 hours. Test results are shown in Figure 55. Regulated pressure was maintained constant at 20.25 psia. A subsequent run was made at an initial temperature of 24°F and maintained for 18 minutes. Regulated pressure was maintained constant at 20.05 psia,which is lower than the ambient temperature test. Test data are shown in Figure 56. A final test was performed after the feed system had been operated in the coast mode operation. The propellant temperature at initiation of the test was 18°F and the test duration 32 minutes. Regulated pressure was maintained constant at 20.0 psia. These data are shown in Figure 57.

6.3.3.3 Liquid Withdrawal

Test runs were also performed with liquid withdrawal from the tank at the flow rate of 3×10^{-5} lb/sec. The test history for an eight hour run, started at 67°F, is shown in Figure 58. Regulated pressure level

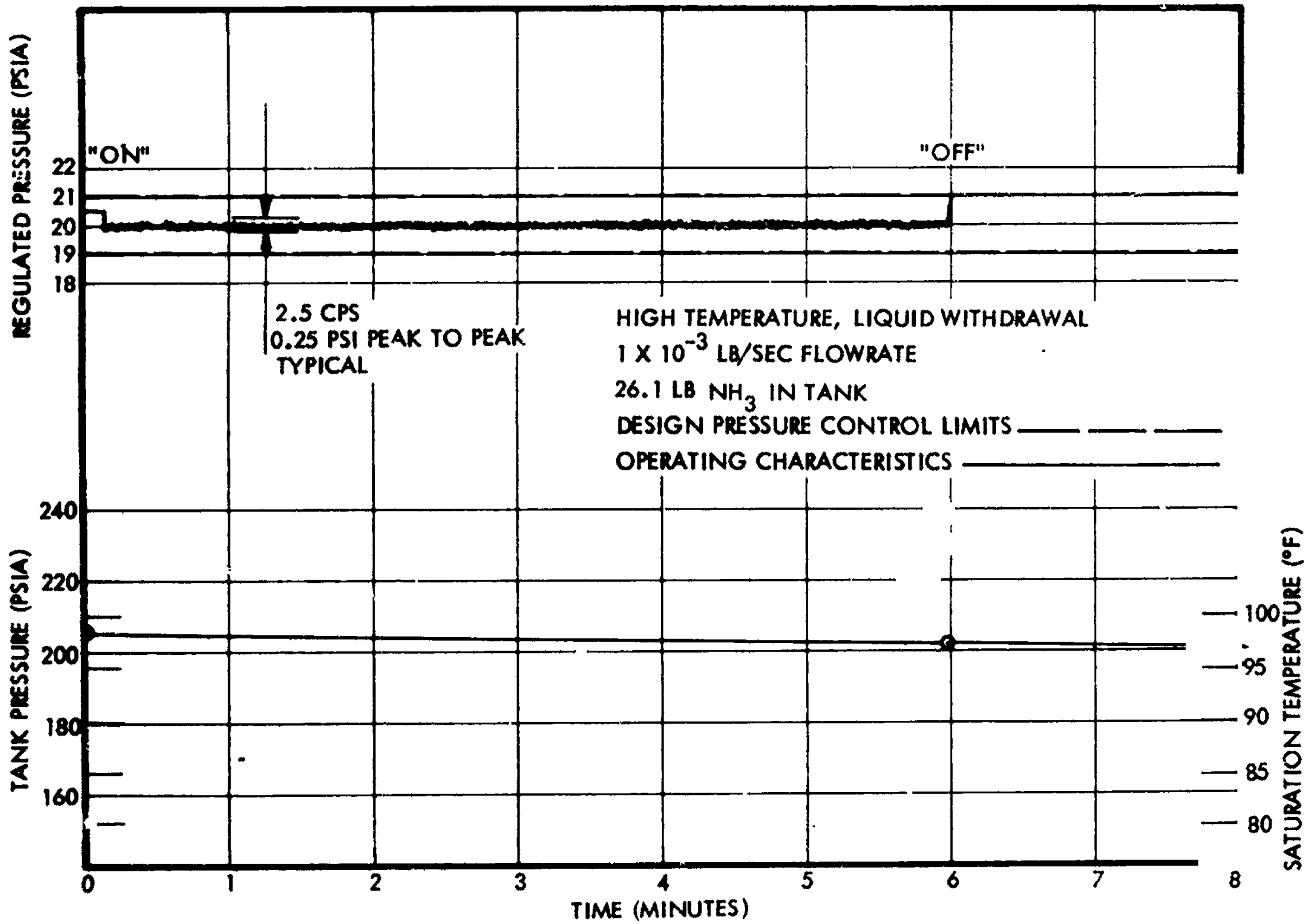


Figure 53. High Temperature, Liquid Phase, Steady-State Maximum Flow Regulation Characteristics, Initial Series

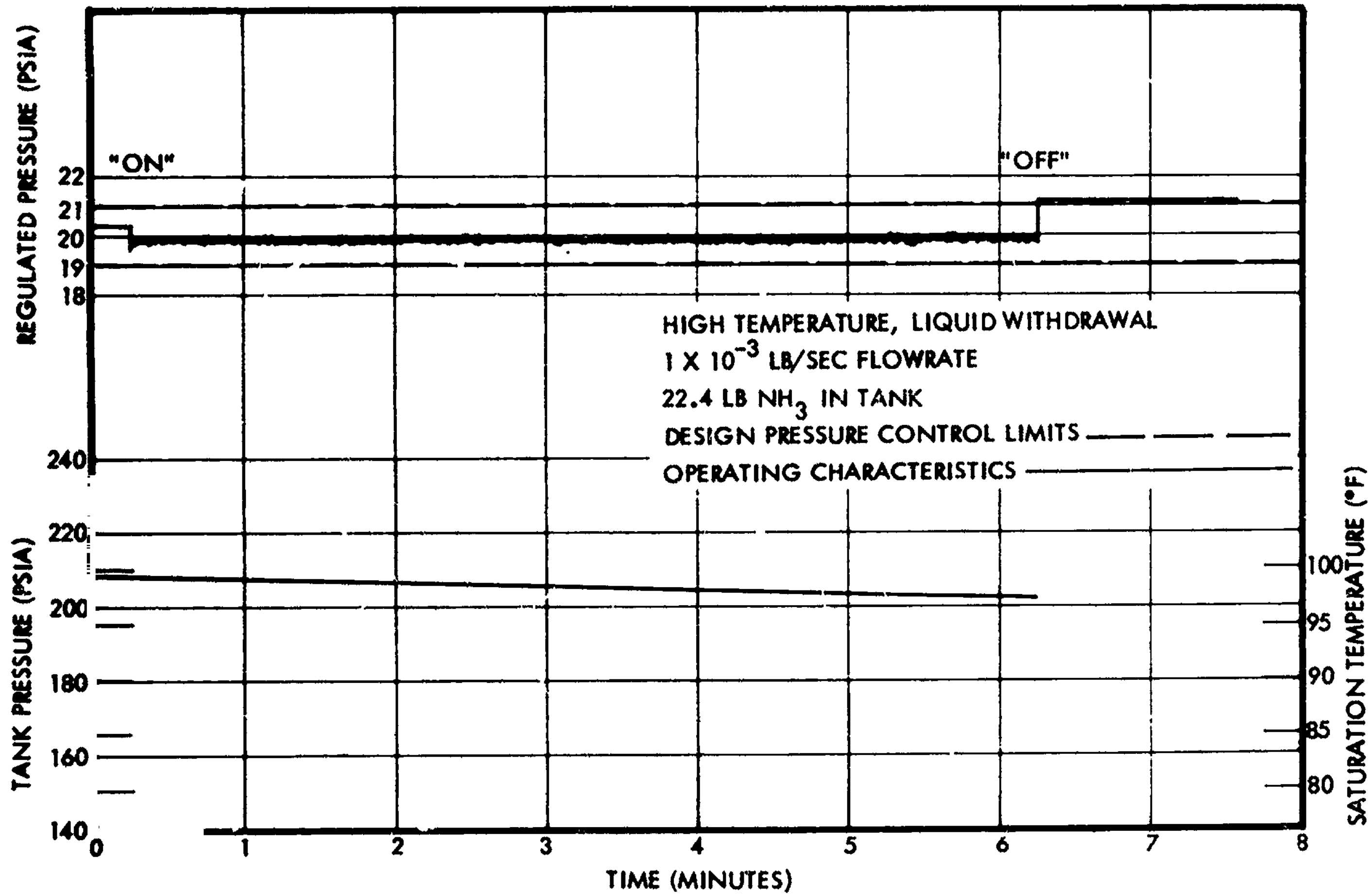


Figure 54. High Temperature, Liquid Phase, Steady-State Maximum Flow Regulation Characteristics, Final Series

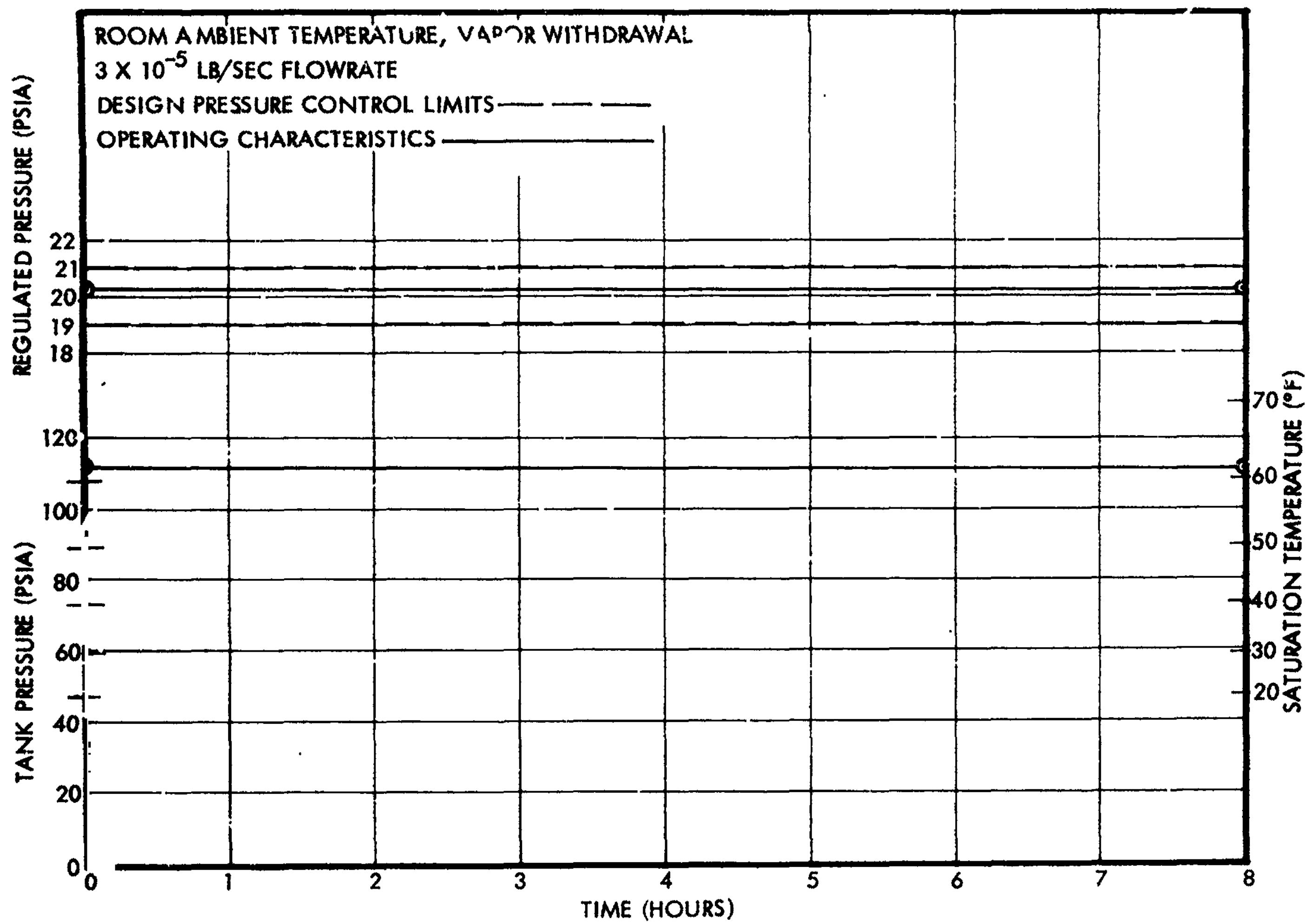


Figure 55. Ambient Temperature, Vapor Phase, Steady-State Low Flow Regulation Characteristics, Initial Series

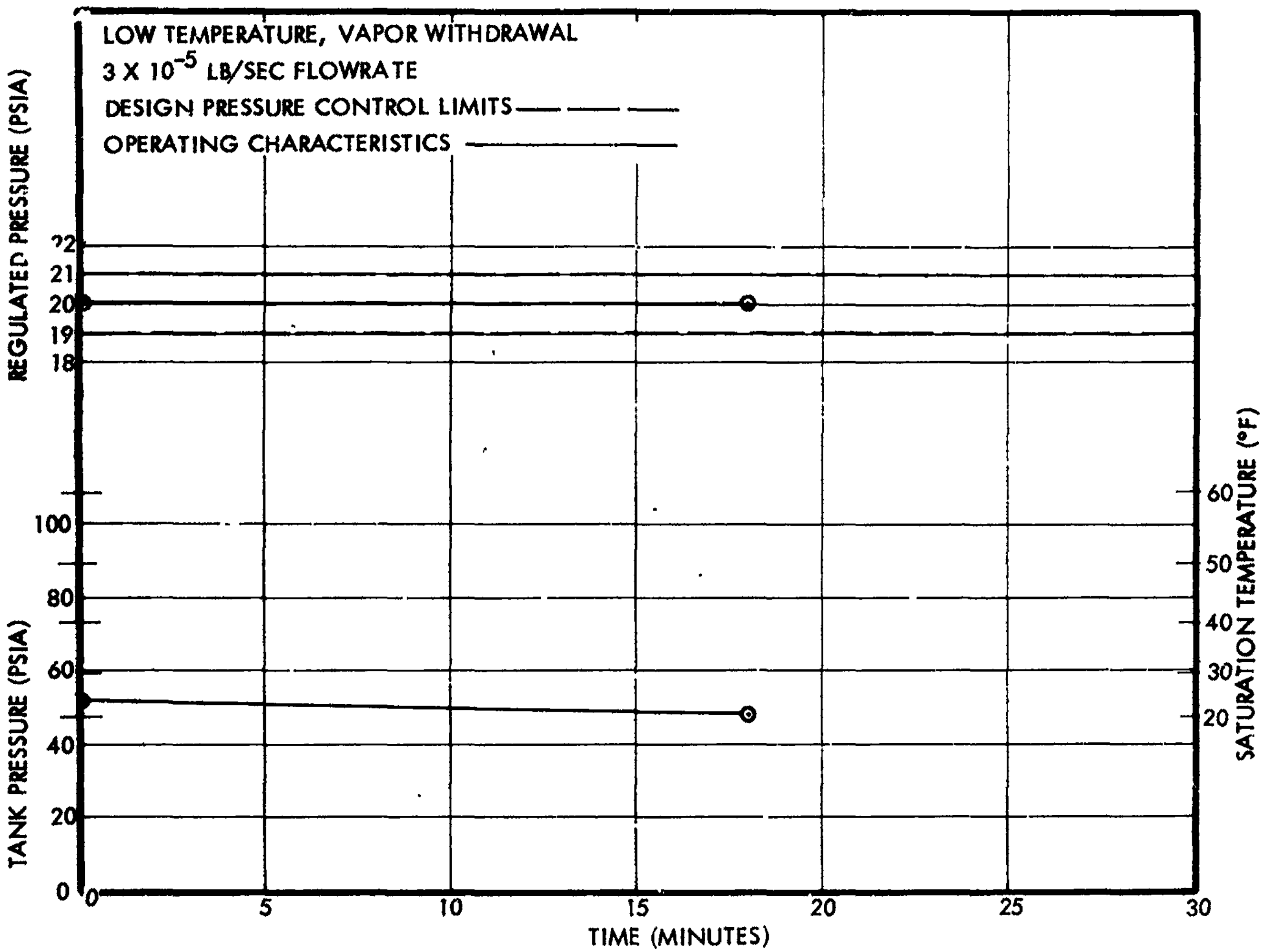


Figure 56. Low Temperature, Vapor Phase, Steady-State Low Flow Regulating Characteristics, Initial Series

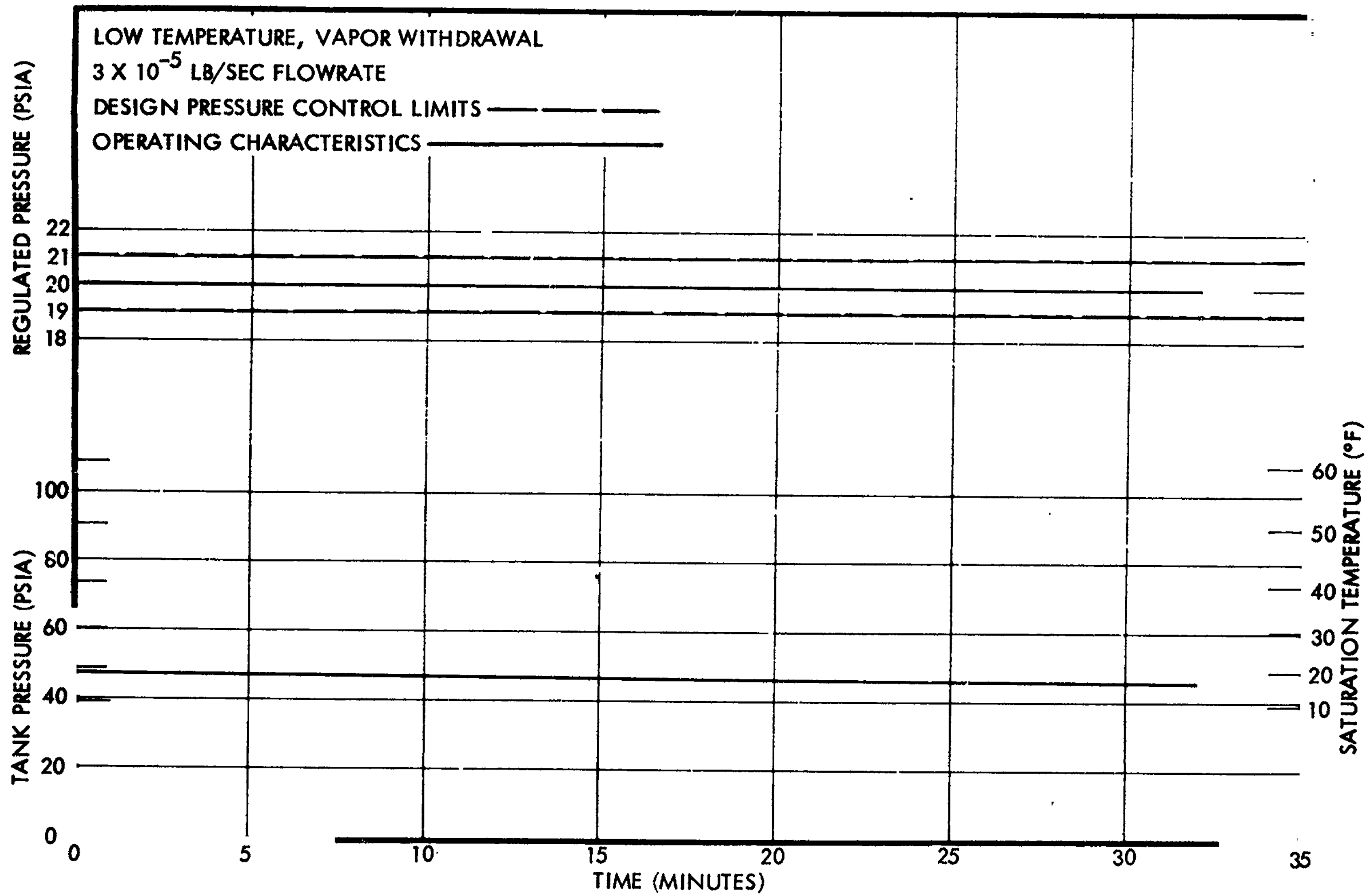


Figure 57. Low Temperature, Vapor Phase, Steady-State Low Flow Regulating Characteristics, Final Series

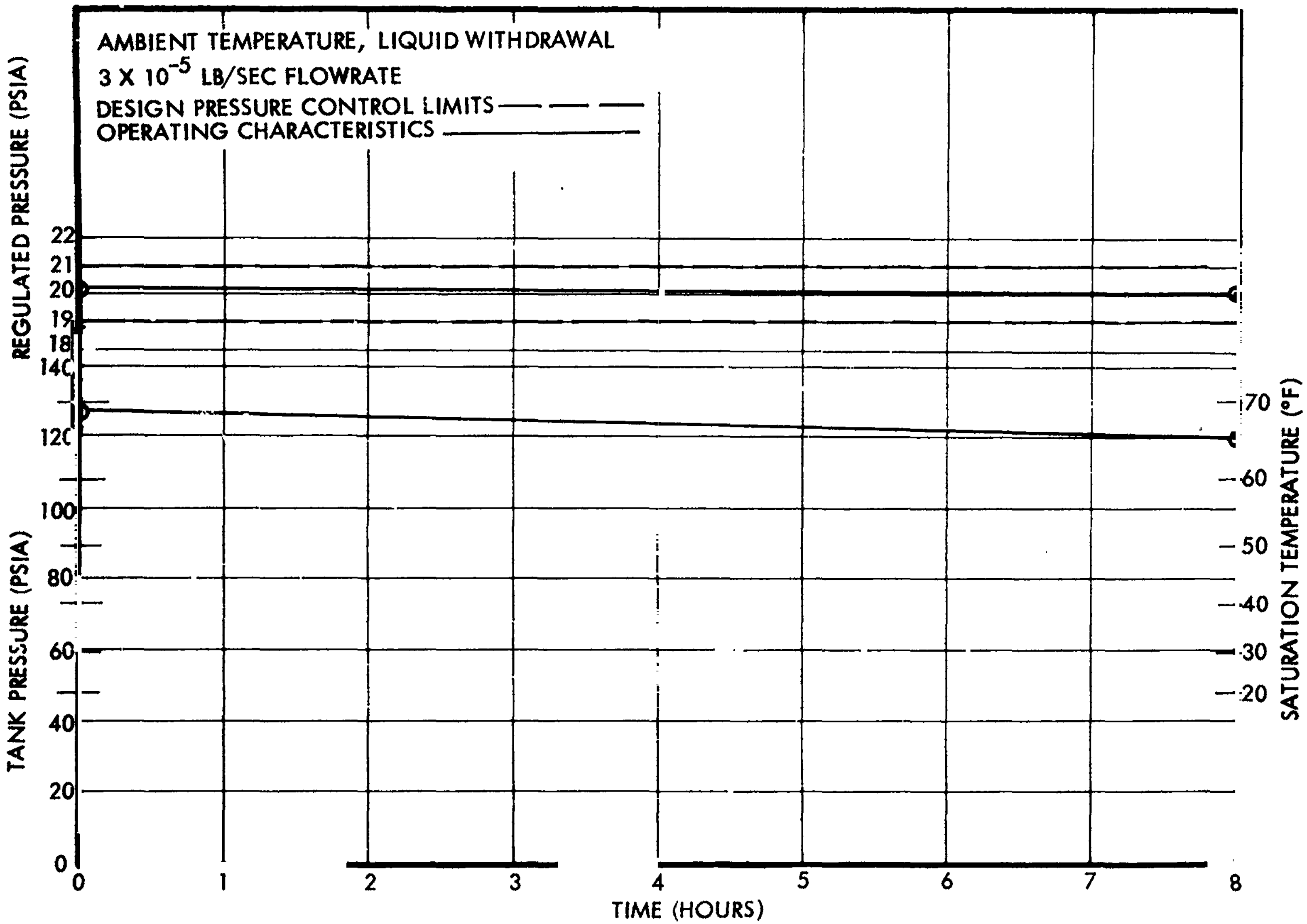


Figure 58. Ambient Temperature, Liquid Phase, Steady-State Low Flow Regulating Characteristics, Initial Series

changed gradually from 20.2 psia at the beginning of the test to 20.0 psia at the end. Test results for a subsequent 30 minute test, started at 22°F, are shown in Figure 59. Regulation level was constant at 19.8 psia. Test results for the final test conducted after completion of the coast mode operation are shown in Figure 60. Test duration was 30 minutes and initiation temperature 22°F. The amount of ammonia in the propellant tank was 28.5 lb for the initial runs and 25.0 lb for the final run, or 81% and 68% of full tank capacity, respectively.

6.3.4 Test Results for System Operating Characteristics at High Pulse Mode Duty Cycle

6.3.4.1 Performance Requirements

As a typical requirement for this mode of operation, the system flow demand has been determined to be a 3 percent duty cycle at a flow rate of 1×10^{-3} lb/sec and a flow ON-time of 0.10 second.

6.3.4.2 Vapor Withdrawal

Test results for the pulsed flow operational mode are summarized in Figures 61, 62, 63, and 64. The figures are for the cases of the initial test at low temperature, initial test at high temperature, final test at low temperature, and final test at high temperature. The pressure regulator characteristics were quite similar in all cases. The regulator lockup pressure was 20.25 psia, and the drop due to the flow demand was 1.0 psi at low temperature and 0.75 psi at high temperature. Pressure regulation was at all times within the design goal limits of 20 $\pm$ 1.0 psia. In order to best utilize the timing circuits available to pulse the flow control valves, a flow ON time of 0.3 second was selected to match the requirement for a 3% duty cycle.

Test period for each of the test conditions was two hours. The data presented in Figures 61 through 64 is typical for the entire time period.

6.3.4.2 Liquid Withdrawal

With liquid withdrawal under pulsed operation at high temperature, the feed system exhibited no difficulties in meeting the pressure regulation design goal of 20 $\pm$ 1.0 psia. Data for these tests is shown in Figures 65 and

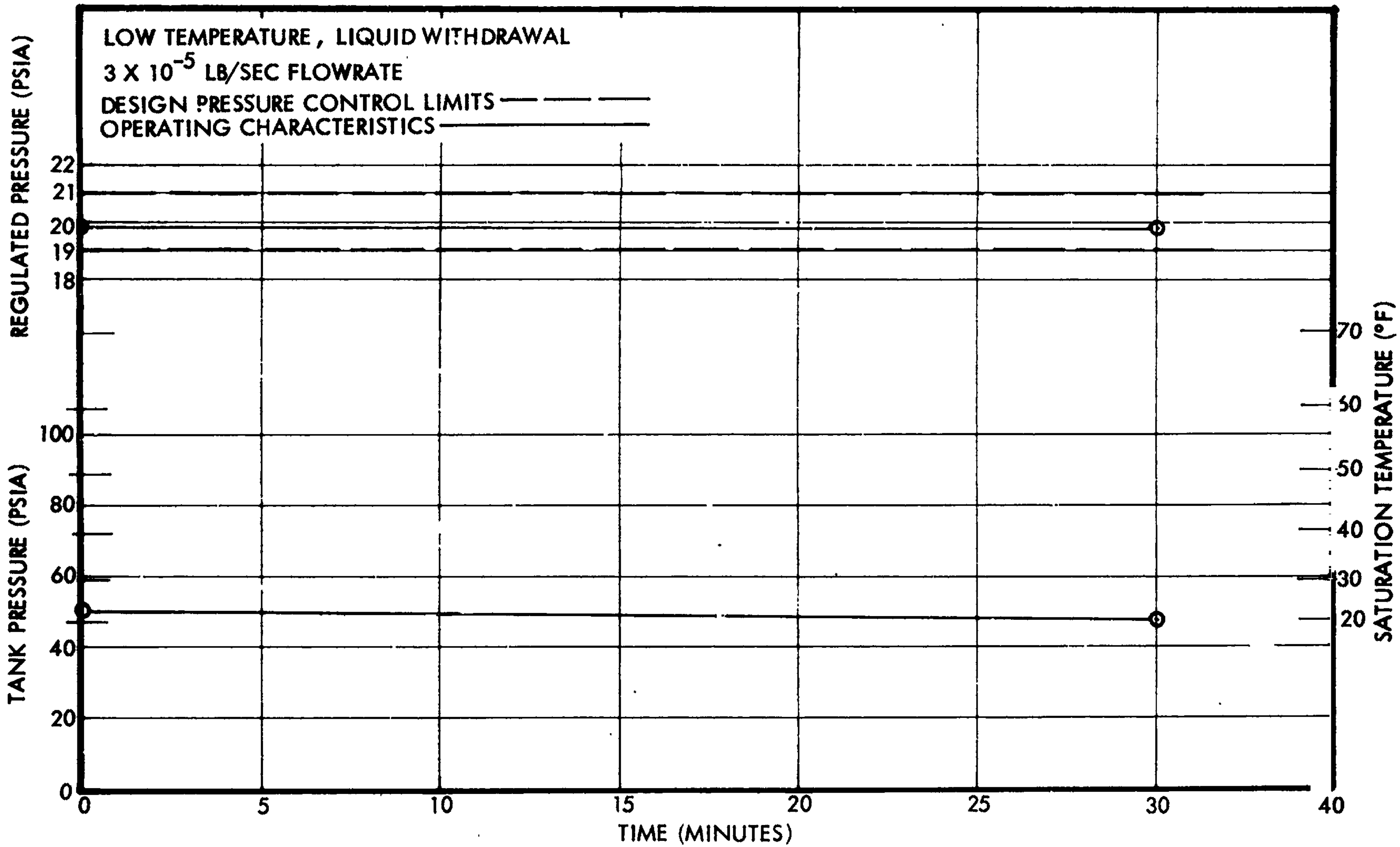


Figure 59. Low Temperature, Liquid Phase, Steady-State Low Flow Regulating Characteristics, Initial Series

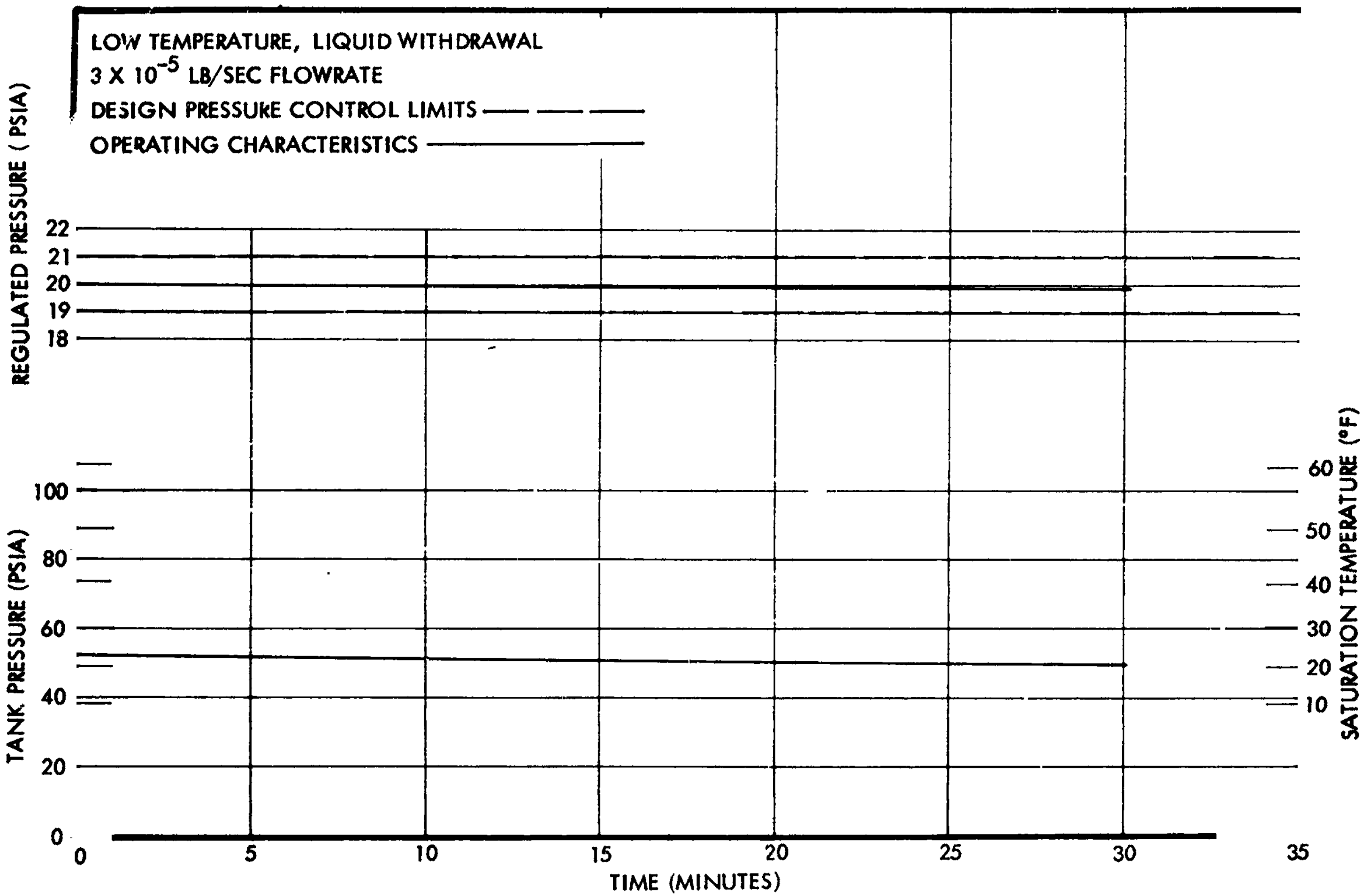


Figure 60. Low Temperature, Liquid Phase, Steady-State Low Flow Regulating Characteristics, Final Series

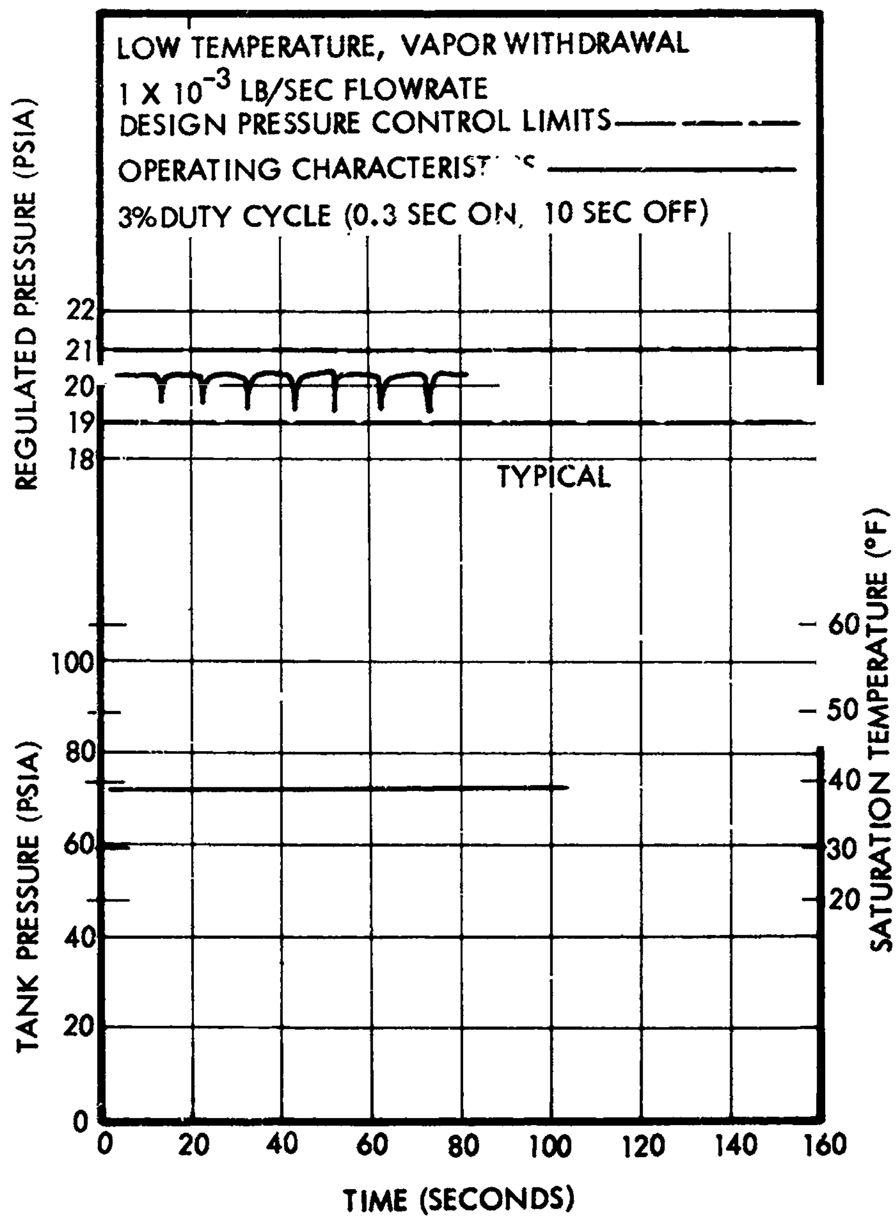


Figure 61. Low Temperature, Vapor Phase, Pulsed Flow Operating Characteristics, Initial Series

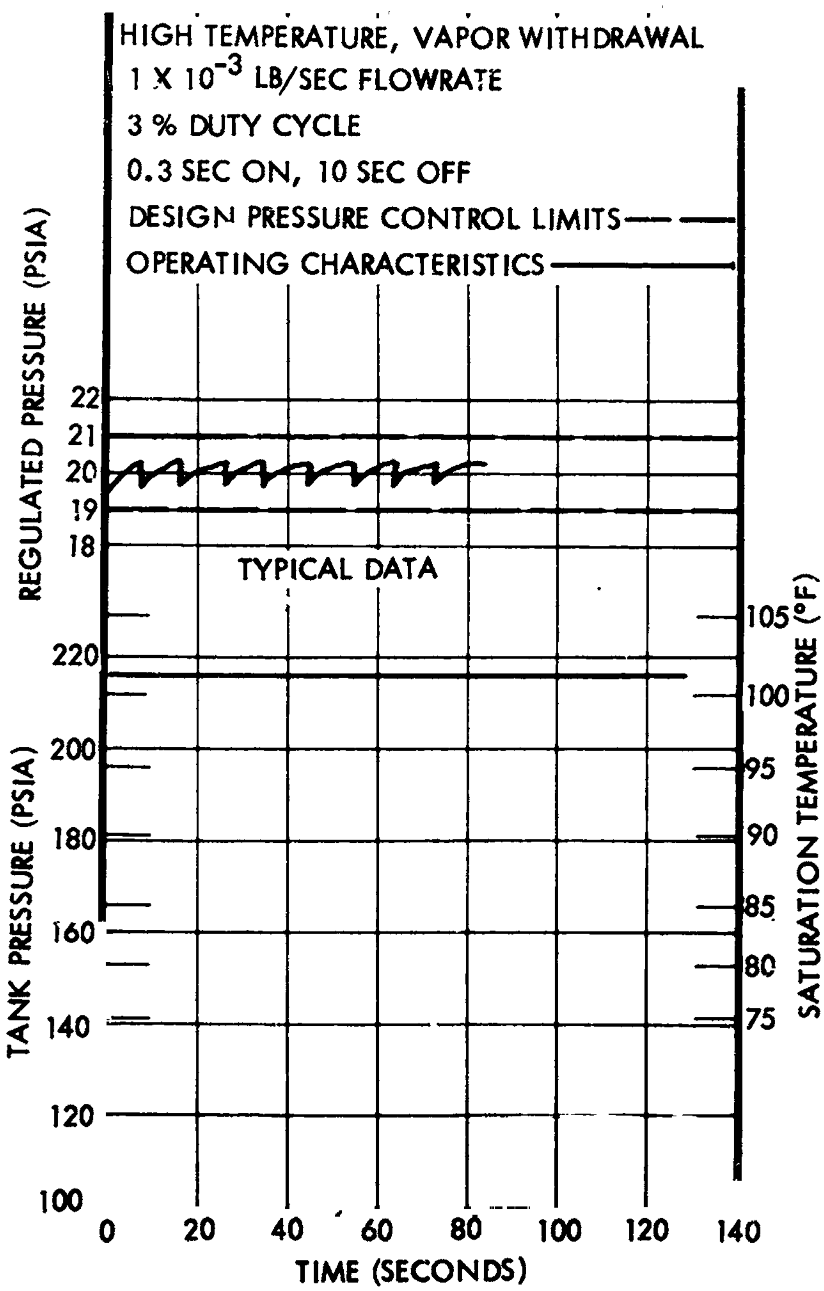


Figure 62. High Temperature, Vapor Phase, Pulsed Flow Operating Characteristics, Initial Series

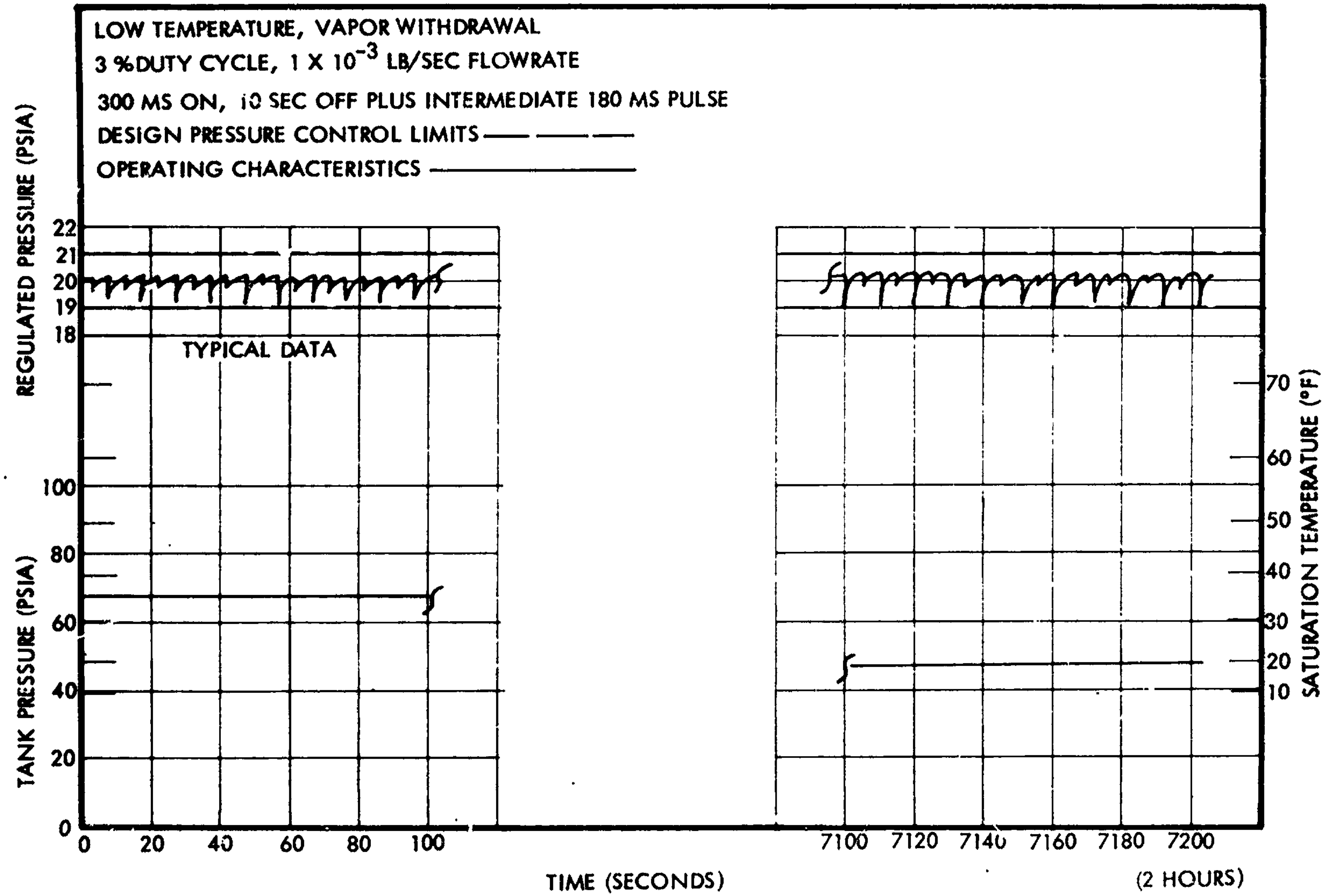


Figure 63. Low Temperature, Vapor Phase, Pulsed Flow Operating Characteristics, Final Series

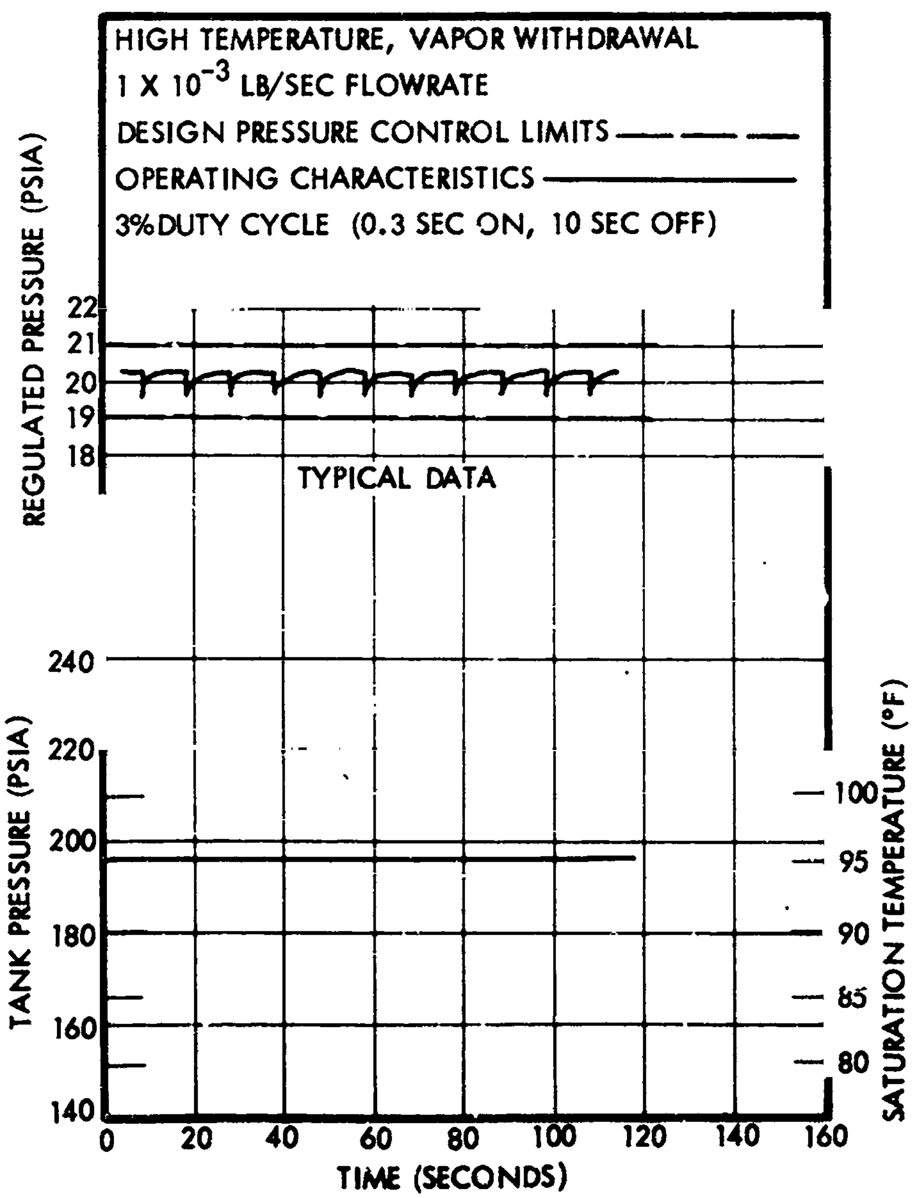


Figure 64. High Temperature, Vapor Phase, Pulsed Flow Operating Characteristics, Final Series

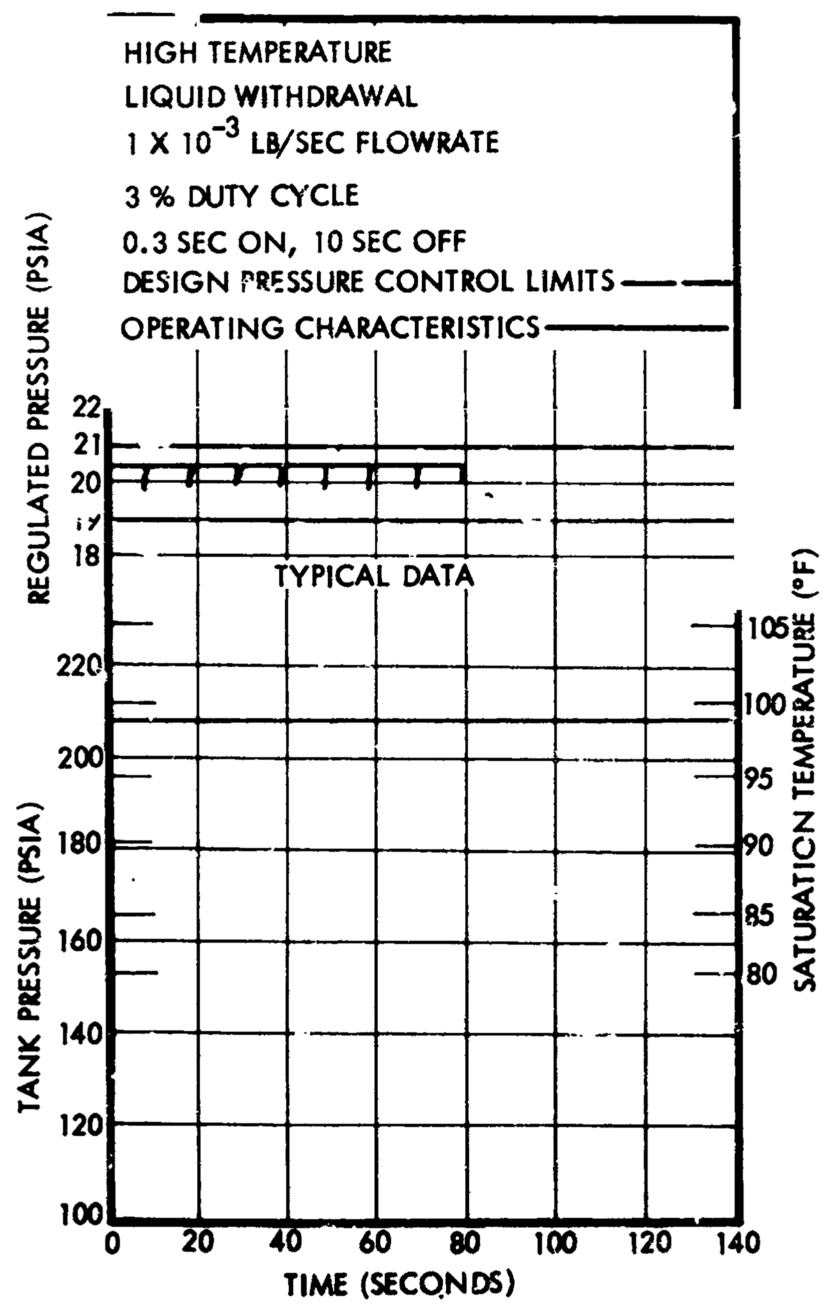


Figure 65. High Temperature, Liquid Phase, Pulsed Flow Operating Characteristics, Initial Series

66 for the tests conducted before and after the coast mode operation. The lockup pressure was somewhat higher than with vapor withdrawal (20.5 psia versus 20.25 psia); however, the drop in pressure during the flow pulse was only about 0.6 psi.

Test results at low temperature are shown in Figures 67 and 68 (before and after the coast mode test). Operation in the pulse mode with an ON-time of 0.3 second caused the system to go to high lockup pressure, exceeding the design goal limits, as well as the original regulation requirement of 20 $\pm$ 2.0 psia. It should be noted that the high lockup occurred only on alternate pulses. Whenever the flow command was initiated from high lockup, the propellant demand was met entirely by the plenum tank. The plenum pressure did not decrease below the set point of the regulator, which stayed closed for that cycle. On the following command the regulator opened and a substantial amount of liquid ammonia was introduced into the capillary tubes. Vaporization of this ammonia then forced the plenum pressure to high lockup, and the cycle repeated. Reduction of the pulse duration to 0.2 second reduced the maximum lockup within the 20 $\pm$ 2.0 psia limits but not within the design goal of 20 $\pm$ 1.0 psia. Further reduction of the ON-time to 0.1 second did reduce the regulation extremes within the design goal range of 20 $\pm$ 1.0 psia. The regulator cycled at each flow command. The plenum pressure never reached a value from which a flow step would be initiated without decreasing the plenum pressure below the set point of the regulator. Consequently, whenever the regulator opened, the liquid ammonia entering the capillary tubes was limited to an amount such that its resulting vaporization never caused the plenum pressure to exceed the maximum design goal for the lockup pressure.

The above described behavior is the case for the specific size plenum tank included in the feed system. Increase of the tank size would decrease the pressure swings due to liquid vaporization in the capillary tubes. This would permit system operation at pulse lengths in excess of 0.1 second and still adhere to the 20 $\pm$ 1.0 psi design goal limits.

3

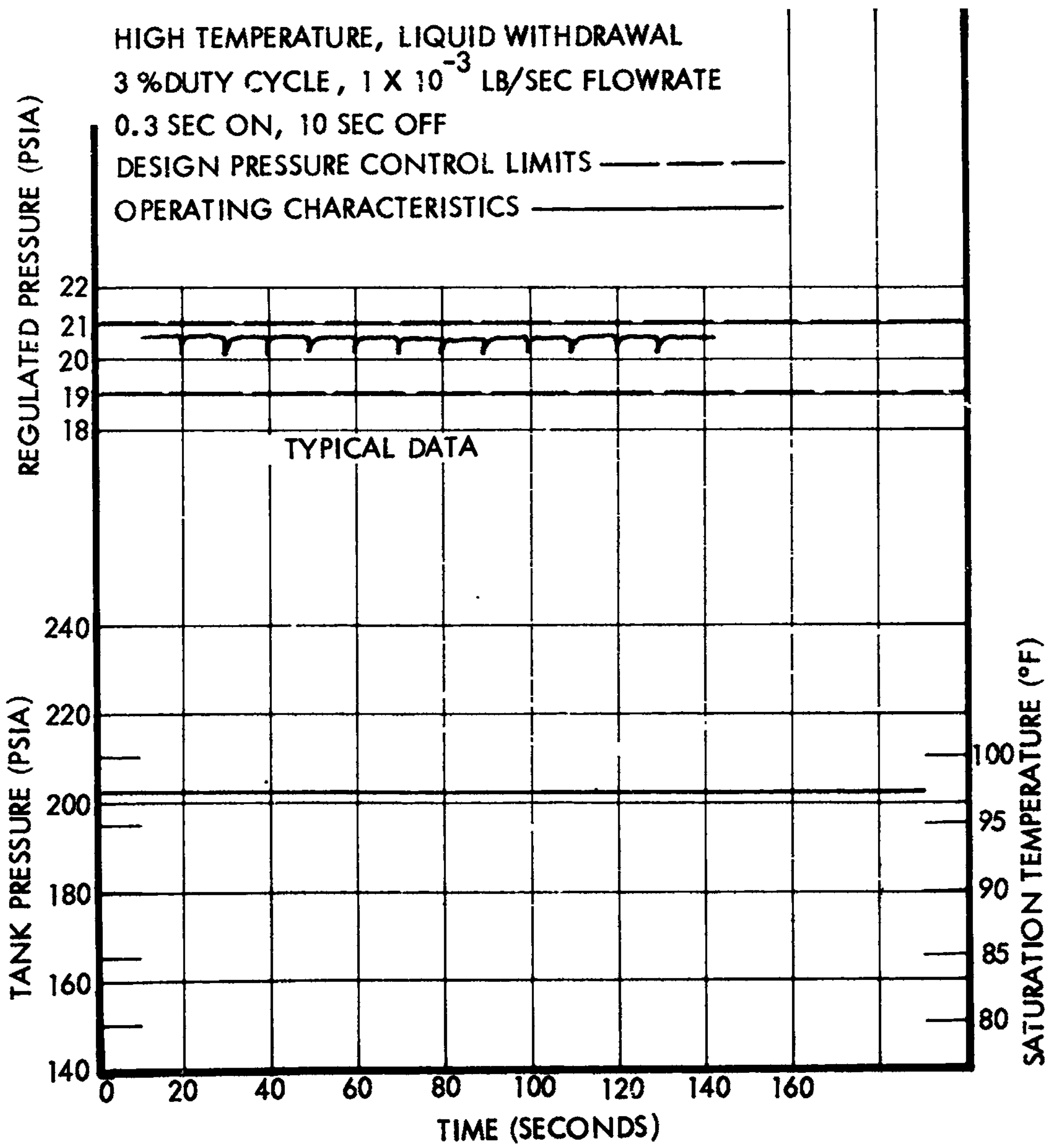


Figure 66. High Temperature, Liquid Phase, Pulsed Flow Operating Characteristics, Final Series

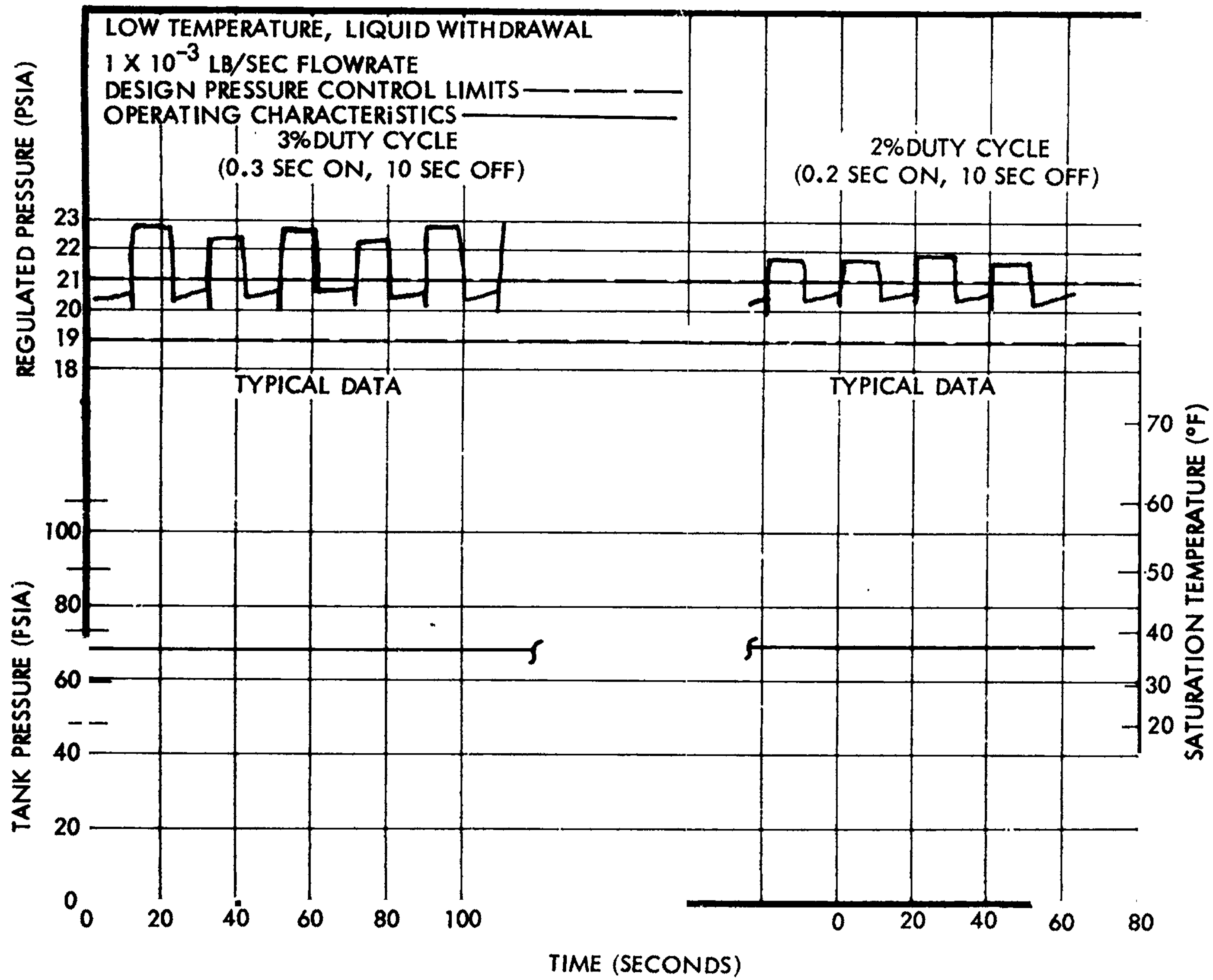


Figure 67. Low Temperature, Liquid Phase, Pulsed Flow Operating Characteristics, Initial Series

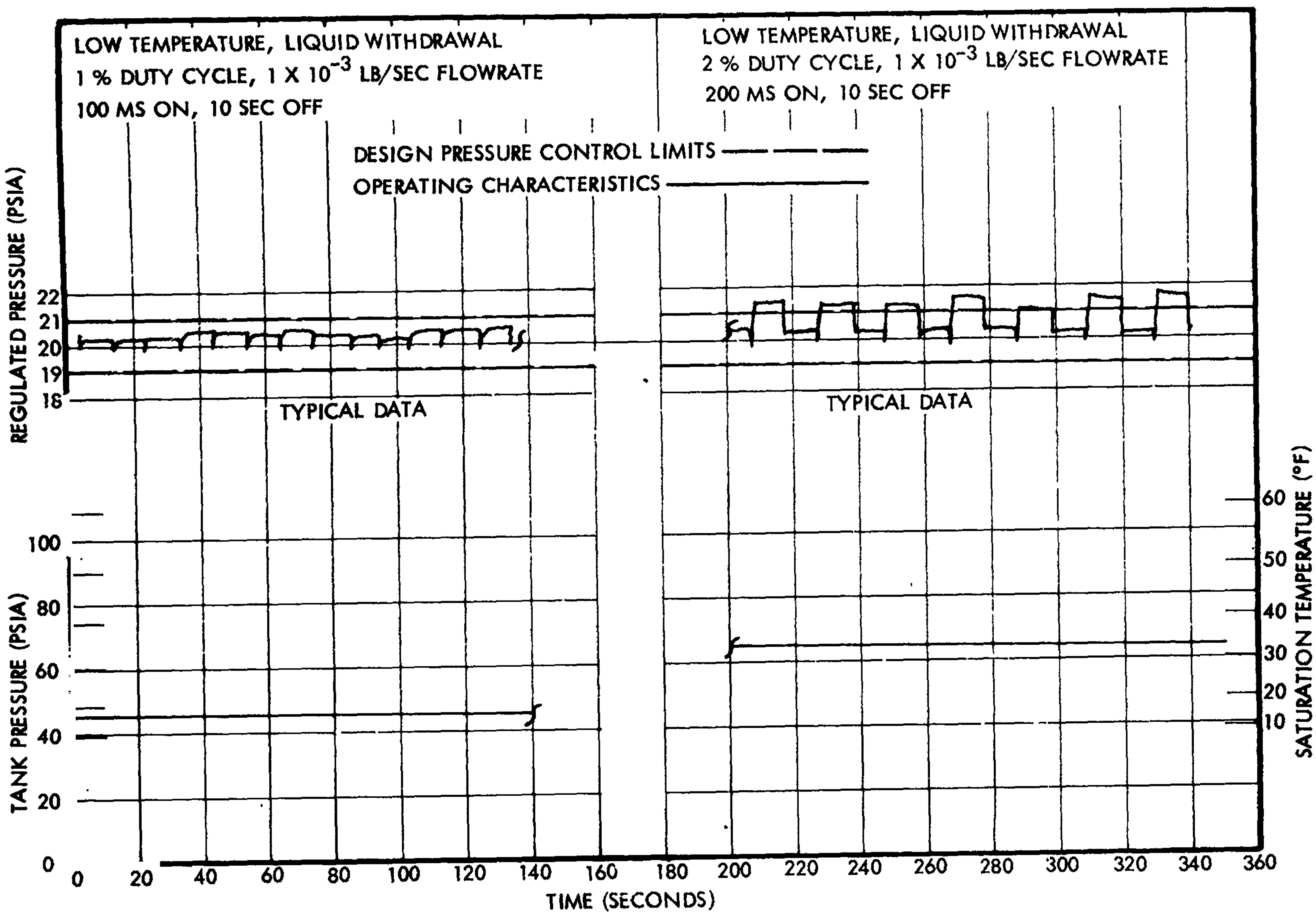


Figure 68. Low Temperature, Liquid Phase, Pulsed Flow Operating Characteristics, Final Series

When the pulse duration was shortened to less than 0.3 second ON-time, it was not possible to maintain the desired duty cycle of 3 percent because of the minimum attainable cycle time of 10 seconds with the particular test equipment. It is evident, however, that the ability of the system to meet the regulation requirements is more critically dependent on the pulse duration than it is on the repetition rate. The regulation capability will be determined by the pulse duration as long as there is sufficient time for the system to reach normal lockup between pulses.

6.3.5 Test Results for System Operating Characteristics at the Coast Mode Duty Cycle

6.3.5.1 Performance Requirements

The feed system is required to perform continuously in the coast mode duty cycle. This is defined in the test plan as pulsed mode operation at a 0.1% duty cycle with the flow ON-time of 0.10 second and a maximum flow of 1×10^{-3} lb/sec.

6.3.5.2 Test Results

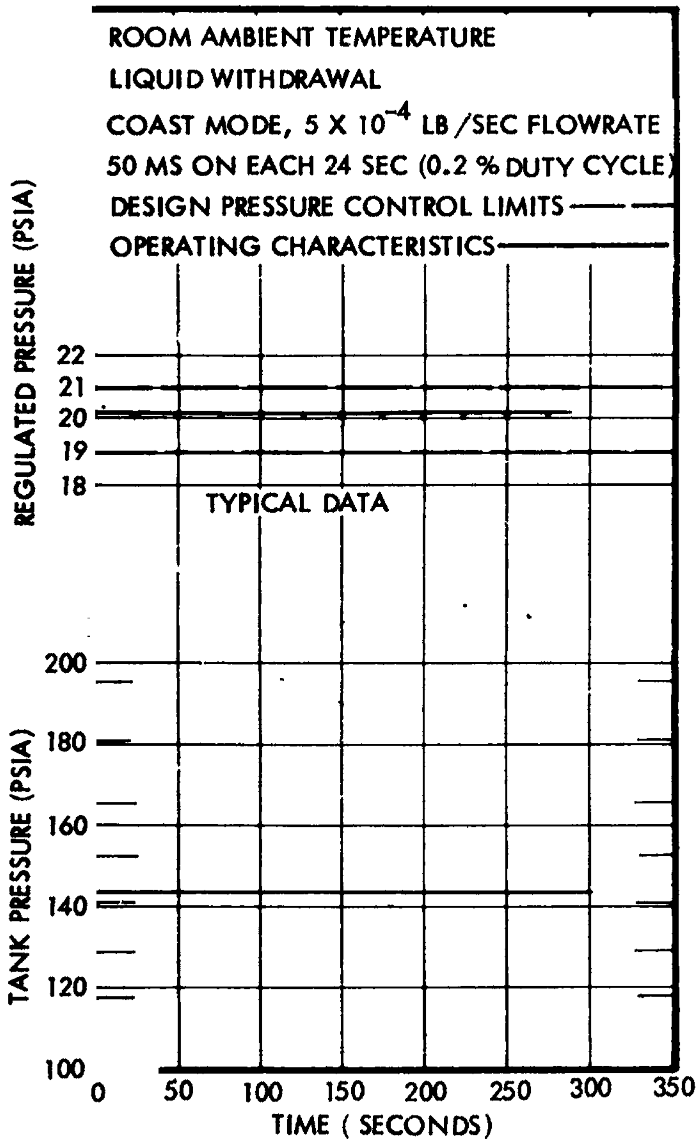
The demonstration system was operated in the coast mode duty cycle for a total of 250 hours. The propellant tank was positioned for liquid phase ammonia withdrawal during daytime hours, but changed to vapor withdrawal for overnight and weekend operation. This schedule allowed the system to be closely monitored when operated with liquid withdrawal, and left unattended with vapor. The purpose was to prevent an unprogrammed and unobserved flow demand caused by test equipment failure while operating with liquid ammonia. Such a failure would have resulted in large amounts of liquid ammonia downstream of the capillary tubes. A similar failure with vapor withdrawal, if left unobserved, would only result in a large amount of ammonia being withdrawn from the storage tank. Actual flow condition during the coast mode testing were 5×10^{-4} lb/sec flow rate with a 0.2% duty cycle consisting of a 50 ms ON-time every 25 seconds. The lower flow rate was used because this was the maximum attainable through the valve used to pulse propellant flow during the coast mode. The duty cycle was increased so that the required amount of propellant would be expelled. Figure 69 shows typical test data with liquid and vapor withdrawal from the propellant tank at the beginning of the coast mode operation. Figure 70 shows similar data at the end of the test. Regulator lockup is 20.2 psia with either phase ammonia entering the regulator. The pressure regulator cycled with each individual flow command. The pressure regulator was subjected to a total of 55,340 flow commands during the coast mode.

6.3.6 Special Tests

Limited testing was performed to investigate the system operational characteristics when operated under conditions more demanding than those stated in the requirements. The results of some of these tests have been described in previous paragraphs. The maximum flow rate tests, for one, were continued for 60 seconds past the system requirement of 300 seconds, and the long time-period moderate flow demand tests were initiated as low as 18°F (25°F was the minimum requirement).

The regulation capability was further investigated at lower temperatures. Additional tests were performed with the propellant temperature at 2°F (32 psia tank pressure). With vapor phase ammonia withdrawn from the propellant tank, the system was able to maintain a 3×10^{-4} lb/sec flow rate at a regulated pressure of 19.0 psia. When the flow rate was increased to 4×10^{-4} lb/sec, the regulation requirement could not be maintained and the plenum pressure dropped to 13.5 psia. During pulse mode operation, the system was capable of responding to 0.2-second duration flow commands at a flow rate of 1×10^{-3} lb/sec, while maintaining the regulated pressure within 20 ± 1.0 psia. Increase of the pulse duration to 0.3 second resulted in the plenum pressure decrease to 18.7 psia during the pulse.

Similar tests were conducted with the propellant tank rotated to the liquid withdrawal mode. The propellant temperature was 0°F (30.5 psia tank pressure). The feed system was subjected to a 300 second duration flow demand at 3×10^{-5} lb/sec, followed by 60 second duration flows at 1×10^{-4}, 1.5×10^{-4}, 2×10^{-4}, 2.5×10^{-4}, and 3×10^{-4} lb/sec. Initial regulated pressure (at 3×10^{-5} lb/sec) was steady at 19.8 psia. At the higher flow rates the regulated pressure started to oscillate at approximately 0.25 Hz and a peak-to-peak magnitude of 0.7 psia. The test sequence was terminated when it appeared that liquid ammonia might be leaving the capillary tubes.



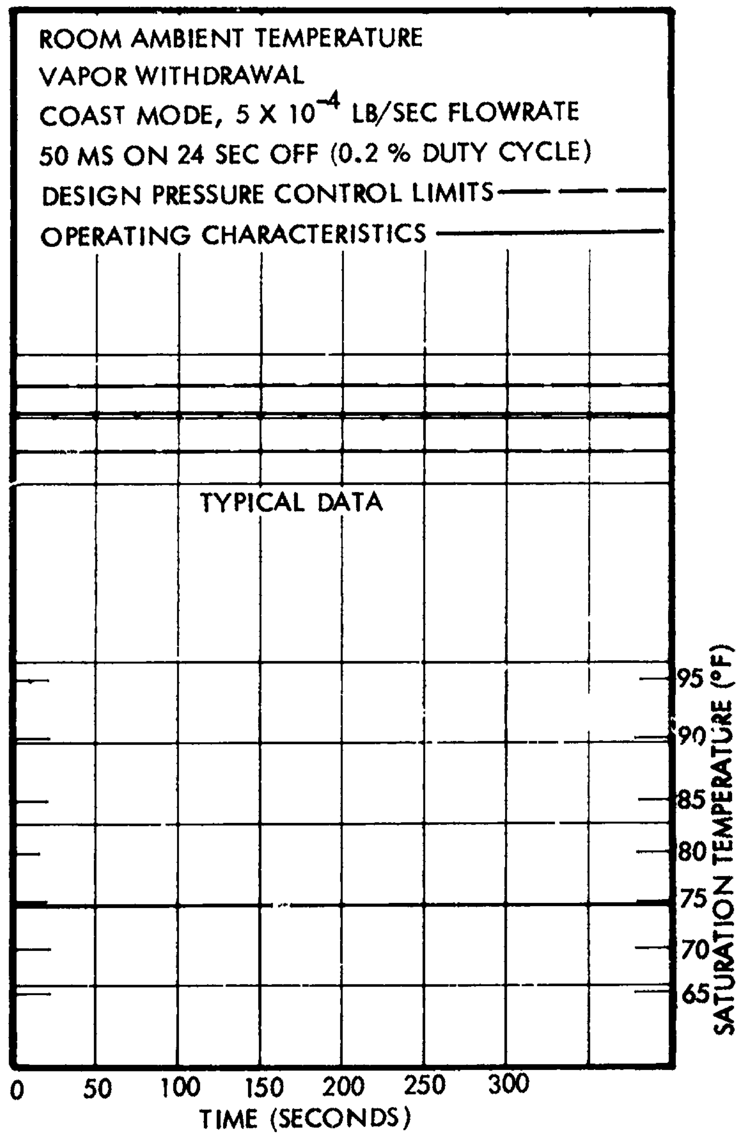


Figure 69. Coast Mode Operating Characteristics, Initial Phase

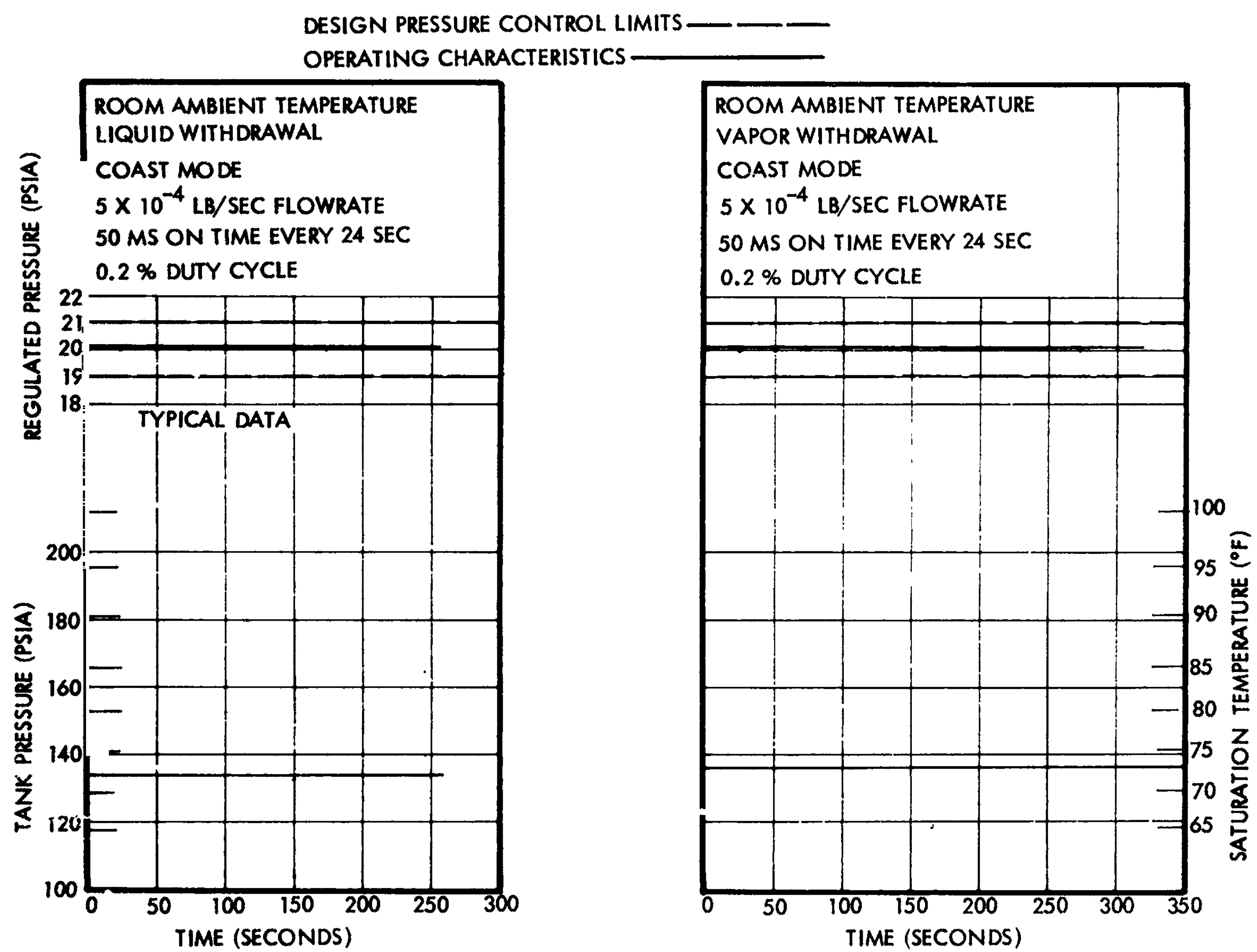


Figure 70. Coast Mode Operating Characteristics, Final Phase

6.3.7 Test Summary

The chronological summary of the test conducted during the demonstration test is presented in Table 4. Included in the table are the flow rate, duty cycle and duration for the various tests, as well as propellant temperature and pressure, individual and cumulative ammonia usage, and individual and cumulative number of pressure regulator cycles.

TABLE 4
FEED SYSTEM TEST SUMMARY

FEED	FLOW RATE LBS/SEC	DUTY CYCLE	TEMP. °F	TANK PRESS. PSIA	DURATION MINUTES	NH_3 USAGE INDIV.	NH_3 USAGE CUMUL.	REGULATOR CYCLES INDIV.	REGULATOR CYCLES CUMUL.
Vapor	$1x10^{-3}$	S/S	53 avg	90 avg	10	0.60	0.60	---	---
Liquid	$1x10^{-3}$	S/S	55	80	6	0.36	0.96	360	360
Vapor	$1x10^{-3}$	S/S	42	73	6	0.36	1.32	---	360
Liquid	$1x10^{-3}$	S/S	38	67	6	0.36	1.68	360	720
Vapor	$3x10^{-5}$	S/S		112-111	420	0.87	2.55	---	720
Liquid	$3x10^{-5}$	S/S		128-120	420	0.87	3.42	---	720
Vapor	$1x10^{-3}$	1% .6sec"on"	27		37	0.02	3.44	40	760
Vapor	$3x10^{-5}$	S/S		52-48	18	0.03	3.47	---	760
Vapor	$1x10^{-3}$	1% .6sec"on"		49	15	0.01	3.48	15	775
Liquid	$3x10^{-5}$	S/S		50-48	30	0.05	3.53	---	775
Liquid	$1x10^{-3}$	1% .6sec"on"			22	0.03	3.56	25	800
Liquid	$1x10^{-3}$	Variable			40	0.02	3.58	50	850
Liquid	$1x10^{-3}$	S/S	40	72-62	6	0.36	3.94	360	1210
Liquid	$1x10^{-3}$	3% .3sec"on"		68	110	0.20	4.14	660	1870
Liquid	$1x10^{-3}$	2% .2sec"on"		69	26	0.03	4.17	156	2026
Vapor	$1x10^{-3}$	3% .3sec"on"		72	110	0.20	4.37	660	2686
Vapor	$1x10^{-3}$	S/S		70-64	6	0.36	4.73	---	2686
Vapor	$1x10^{-3}$	3% .3sec"on"	100	216	120	0.20	4.93	720	3406
Vapor	$1x10^{-3}$	S/S	102	214-203	6	0.36	5.29	---	3406

Table 4

FEED SYSTEM TEST SUMMARY (Continued)

FEED	FLOW RATE LBS/SEC	DUTY CYCLE	TEMP. °F	TANK PRESS. PSIA	DURATION MINUTES	NH_3 USAGE INDIV.	NH_3 USAGE CUMUL.	REGULATOR CYCLES INDIV.	REGULATOR CYCLES CUMUL.
Liquid	$1x10^{-3}$	3%.3sec"on"		208	120	0.20	5.49	720	4126
Liquid	$1x10^{-3}$	S/S		205-201	6	0.36	5.85	375	4500
Liquid	$1x10^{-3}$	1%.1sec"on"			120	0.01	5.86	300	4800
Vapor	$5x10^{-4}$	0.2% 50ms"on"		144	2 hr	0.01	5.87	300	5100
Liquid	$5x10^{-4}$	0.2% 50ms"on"			5 hr	0.02	5.89	720	5800
Vapor	$5x10^{-4}$	0.2% 50ms"on"			15 hr	0.05	5.94	2160	7960
Liquid	$5x10^{-4}$	0.2% 50ms"on"			[illegible] hr	0.03	5.97	1300	9260
Vapor	$5x10^{-4}$	0.2% 50ms"on"		136	15 hr	0.05	6.02	2160	11,420
Liquid	$5x10^{-4}$	0.2% 50ms"on"			9 hr	0.03	6.05	1300	12,720
Vapor	$5x10^{-4}$	0.2% 50ms"on"		136	63 hr	0.23	6.28	9100	21,820
Liquid	$5x10^{-4}$	0.2% 50ms"on"			9 hr	0.03	6.31	1300	23,100
Vapor	$5x10^{-4}$	0.2% 50ms"on"			15 hr	0.05	6.36	2160	25,300
Liquid	$5x10^{-4}$	0.2% 50ms"on"			9 hr	0.03	6.39	1300	26,600
Vapor	$5x10^{-4}$	0.2% 50ms"on"			15 hr	0.05	6.44	2160	28,760
Liquid	$5x10^{-4}$	0.2% 50ms"on"			9 hr	0.03	6.47	1300	30,060
Vapor	$5x10^{-4}$	0.2% 50ms"on"			15 hr	0.05	6.52	2160	32,220
Vapor	$1x10^{-3}$	*3% .3sec"on"		67-48	120	0.30	6.82	1440	33,660
Vapor	$3x10^{-5}$	S/S		46-45	32	0.05	6.87	---	33,660
Vapor	$1x10^{-3}$	1%.1sec"on"		48-48	60	0.04	6.91	80	33,740
Liquid	$3x10^{-5}$	S/S		52-50	32	0.05	6.96	---	33,740

TABLE 4

FEED SYSTEM TEST SUMMARY (Continued)

FEED	FLOW RATE LBS/SEC	DUTY CYCLE	TEMP. °F	TANK PRESS. PSIA	DURATION MINUTES	N_3 USAGE INDIV.	N_3 USAGE CUMUL.	REGULATOR CYCLES INDIV.	REGULATOR CYCLES CUMUL.
Liquid	$1x10^{-3}$	Variable		45-65	35	0.04	7.00	200	33,940
Liquid	$1x10^{-3}$	S/S		72-65	6	0.36	7.36	260	34,200
Liquid	$1x10^{-3}$	Variable		65	50	0.10	7.46	300	34,500
Vapor	$1x10^{-3}$	S/S		86-72	6	0.36	7.82	---	34,500
Vapor	$1x10^{-3}$	S/S		72	6	0.36	8.18	---	34,500
Vapor	$1x10^{-3}$	3%*.3sec"on"		71	60	0.16	8.34	720	35,220
Vapor	$5x10^{-4}$	0.2% 50ms"on"			66 hr	0.24	8.58	9400	44,620
Vapor	$1x10^{-3}$	S/S		215-180	6	0.36	8.94	---	44,620
Vapor	$1x10^{-3}$	3%*13sec"on"		196-192	120	0.32	9.26	1440	46,060
Liquid	$1x10^{-3}$	S/S		208-202	6	0.36	9.62	790	46,850
Liquid	$1x10^{-3}$	3%.3sec"on"		202-198	20	0.05	9.67	240	47,090
Liquid	$9x10^{-4} \rightarrow 1x10^{-4}$	S/S		188	16	0.40	10.07	1200	48,290
Liquid	$1x10^{-3}$	3%*.3sec"on"		190	70	0.17	10.24	800	49,090
Vapor	$3x10^{-4}$	S/S		40	37	0.67	10.91	---	49,090
Vapor	$4.5x10^{-4} \rightarrow 1x10^{-4}$	S/S		32	3	0.03	10.94	---	49,090
Vapor	$3x10^{-5}$	S/S		32	2	---	10.94	---	49,090
Vapor	$1x10^{-3}$	Variable		31	15	0.04	10.98	200	49,290
Liquid	$1x10^{-3}$	Variable		31	15	0.04	11.02	200	49,490
Liquid	$3x10^{-5}$	S/S		30	6	0.01	11.03	---	49,490

TABLE 4

FEED SYSTEM TEST SUMMARY (Continued)

FEED	FLOW RATE LBS/SEC	DUTY CYCLE	TEMP. °F	TANK PRESS. PSIA	DURATION MINUTES	N_3 USAGE INDIV.	N_3 USAGE CUMUL.	REGULATOR CYCLES INDIV.	REGULATOR CYCLES CUMUL.
Liquid	$1x10^{-4} \rightarrow 3x10^{-4}$	S/S		28	6	0.05	11.08	80	49,570
Vapor	$5x10^{-4}$	0.2% 50ms"on"		Variable	24 hr	0.08	11.16	3460	53.030
Vapor	$3x10^{-5}$	S/S		134	120	0.25	11.41	---	53,030
Liquid	$3x10^{-5}$	S/S		128	60	0.13	11.54	---	53,030
Liquid	$5x10^{-4}$	0.2% 50ms"on"		132	6 hr	0.02	11.56	870	53,900
Vapor	$5x10^{-4}$	0.2% 50ms"on"		134	10 hr	0.03	11.59	1440	55,340
Vapor	$3x10^{-5}$	S/S		131	240	0.50	12.09	---	---

*Actually 4.5% due to extra pulse

7. ZERO GRAVITY SIMULATION TESTS

A simulated zero-gravity heat transfer test was performed to verify the propellant flow times that could be sustained at the maximum flow rate. A schematic of the test system is shown in Figure 71. The prototype feed system components were used in this test. The test layout similar to that used in the prototype system test, but with certain modifications. In this test, the prototype feed system propellant tank was filled with a glycerine-water mixture, while liquid phase ammonia was supplied from a separate tank. The glycerine-water mixture used in the propellant tank, on which the capillary tubes were bonded, contained 55 percent glycerine by weight. This mixture was selected because it has a specific combination of physical properties characteristic of ammonia and also a high kinematic viscocity. The physical property combination simulates the $\sqrt{\frac{\alpha}{k}}$ term of Equation (5). In terms of individual properties, this factor is:

$$\sqrt{\frac{\alpha}{k}} = \sqrt{\left(\frac{1}{k\rho C_p}\right)}$$

It can be seen from Equation (5), that by duplicating this factor, the temperature variation of the storage tank wall will be nearly the same for the mixture as for liquid ammonia. This similarity condition will not apply at points away from the tank wall; however, it is only the wall temperature profile that must be duplicated for determining flow times. The heat transfer factor for ammonia and the glycerine-water mixture, as a function of temperature, is shown in Figure 72. At 40°F, the heat transfer factors agree to within approximately 4.5 percent.

The relatively high kinematic viscosity of the glycerine-water mixture diminishes the extent to which natural convection will occur in a system. The square of the ratio of kinematic viscosity of the glycerine-water mixture to that of liquid ammonia as a function of temperature is shown in Figure 73. The ratio of total heat transfer to that of conduction, ϕ, within a system is inversely proportional to the square of kinematic viscosity. Total heat transfer includes the contribution from both conduction and convection. The correlation parameter for determining ϕ is the product,

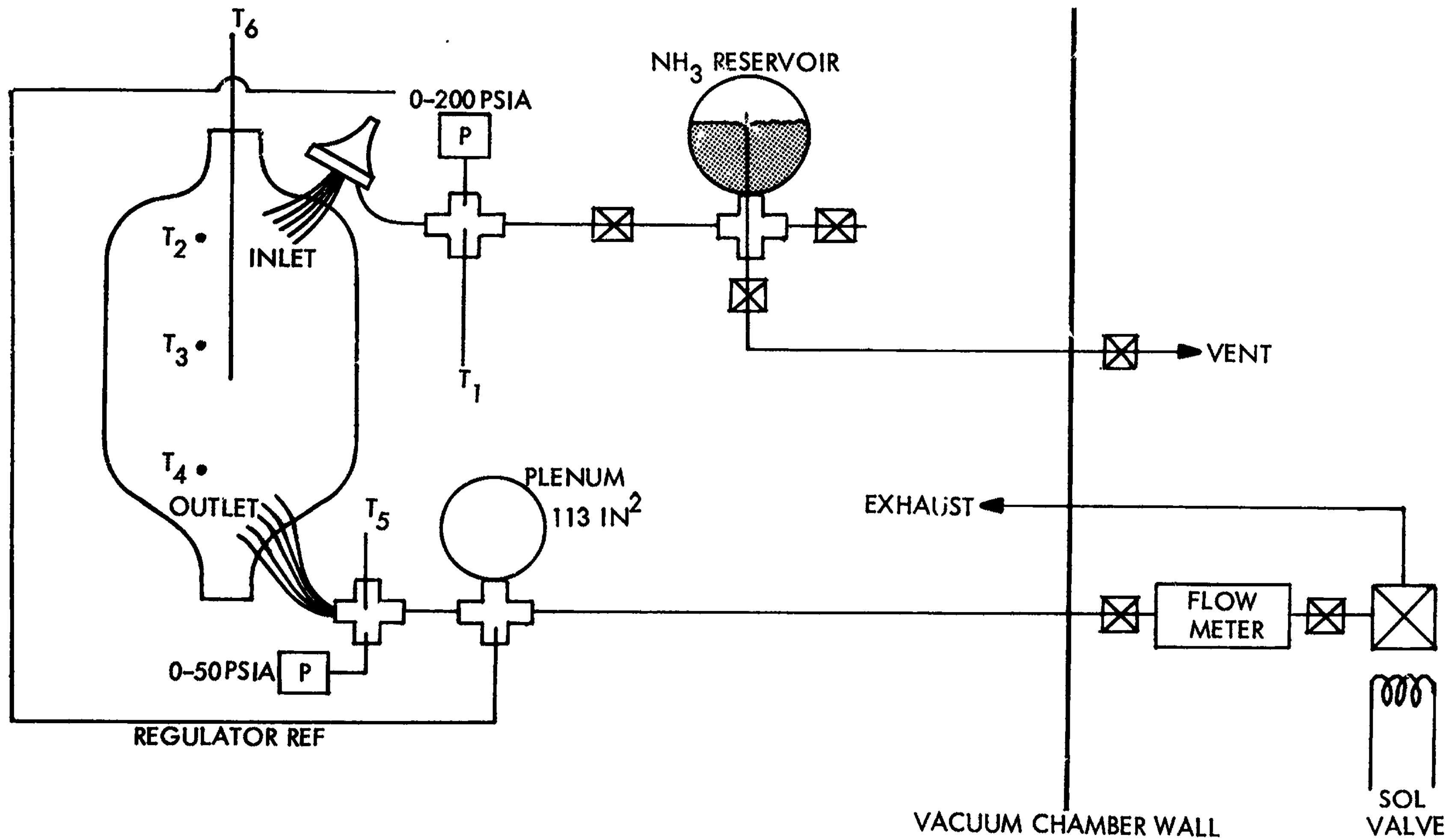


Figure 71. Simulated Zero-Gravity Test Schematic

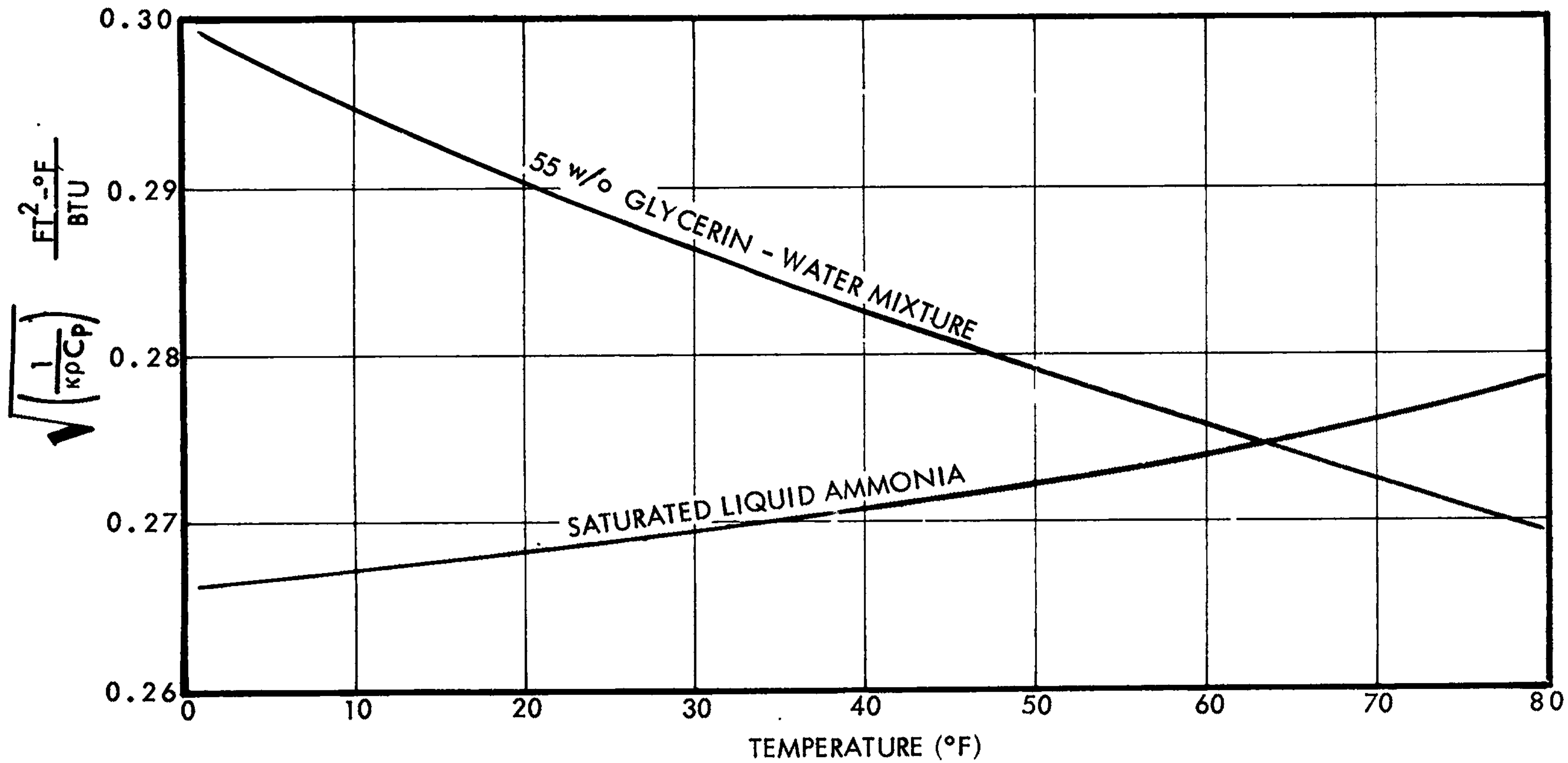


Figure 72. Transient Heat Transfer Factor

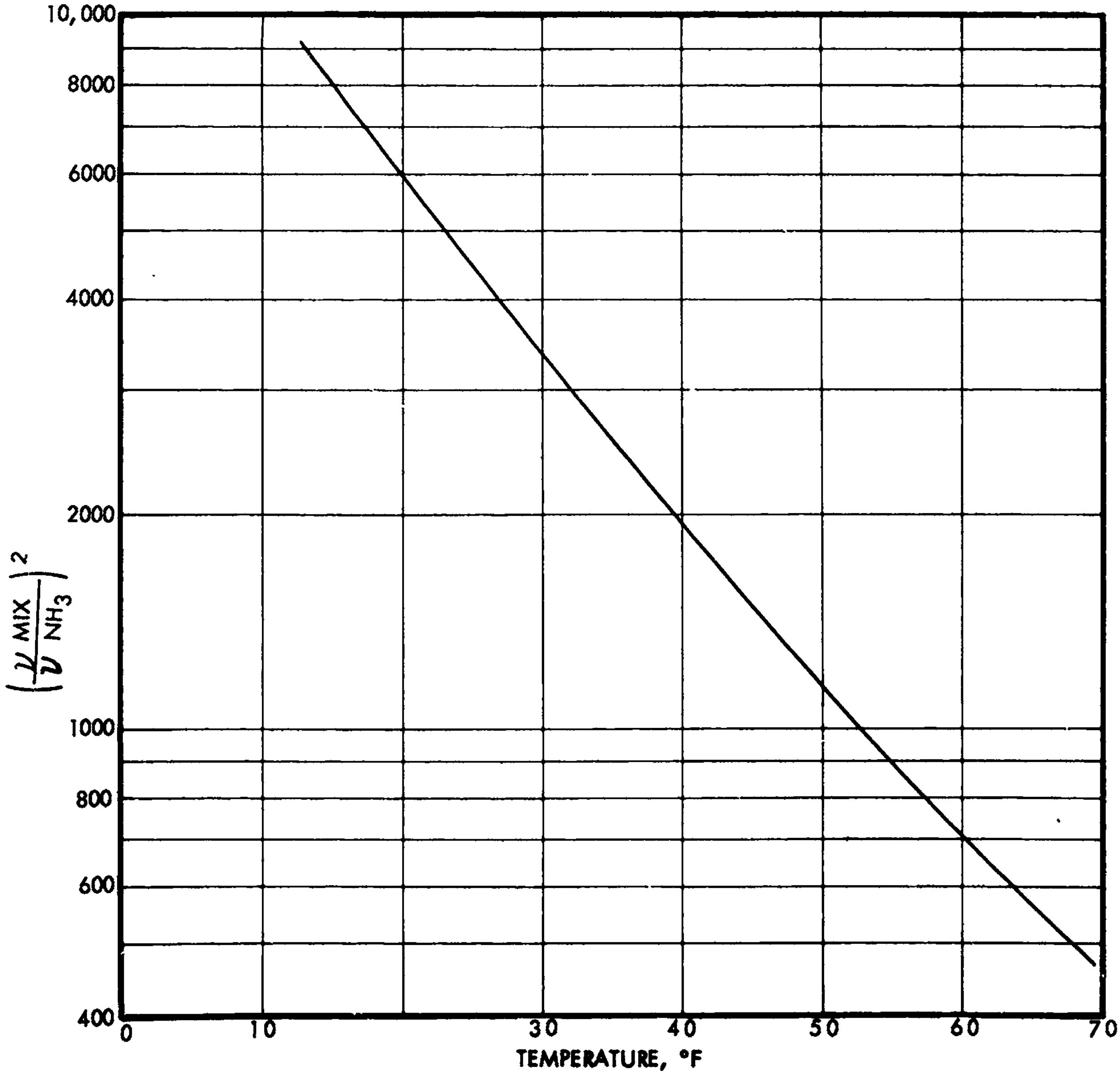


Figure 73. Kinematic Viscosity Factor

$$(N_{Gr} \cdot N_{Pr})$$

where

N_{Gr} = Grashof Number

$$= \frac{\beta g \Delta T \; L^3}{\upsilon^2}$$

β = coefficient of thermal expansion

g = gravitational constant

ΔT = temperature differential

L = characteristic length

υ = kinematic viscosity

N_{Pr} = Prandtl Number

$$= \frac{C_p \mu}{k}$$

C_p = specific heat

μ = absolute viscosity

k = thermal conductivity

For the product $N_{Gr} \cdot N_{Pr} \leq 10^3$, the heat transfer is approximately that due to conduction alone.(2) The value of this product for the test system during the test conditions was less than 500.

The tests were conducted by first allowing the storage tank containing the glycerine-water mixture and capillary tubes, the liquid ammonia storage vessel and the regulator to attain thermal equilibrium. Propellant flow was then initiated and adjusted to 1×10^{-3} lb/sec. The propellant flow was terminated when the delivery pressure limits became erratic. This indicated that a small, but finite quantity of liquid phase ammonia was leaving the capillary tubes. The confirmation of liquid phase in the capillary tube exhaust was made after termination of flow. This was done by noting the pressure rise in system plenum. A rise in the plenum pressure in excess of that attributed to thermal effects would indicate the presence of liquid in the downstream system. Total pressure rise above normal regulator lock-up was approximately 3 psi for those runs in which liquid was exhausted.

The time-temperature profiles of the tests are shown in Figures 74, 75, and 76. Identification of the thermocouples is shown on the schematic in Figure 71. The tests with start temperatures of 46.5°F and 32.3°F were terminated at the time there was indication of liquid phase in the ammonia exhaust from the capillary tube. The flow times were 738 seconds at a start temperature of 46.5°F and 162 seconds at 32.3°F. The 66°F test was terminated after 10 minutes. There was no indication of liquid exhaust during this test. A curve of these flow times is shown in Figure 77. There is fair agreement between the experimental and analytical data at the critical design temperature of 40°F. The system exhibits the capability of maintaining a flow rate of 1×10^{-3} lb/sec for a period in excess of 400 seconds when the initial temperature is 40°F.

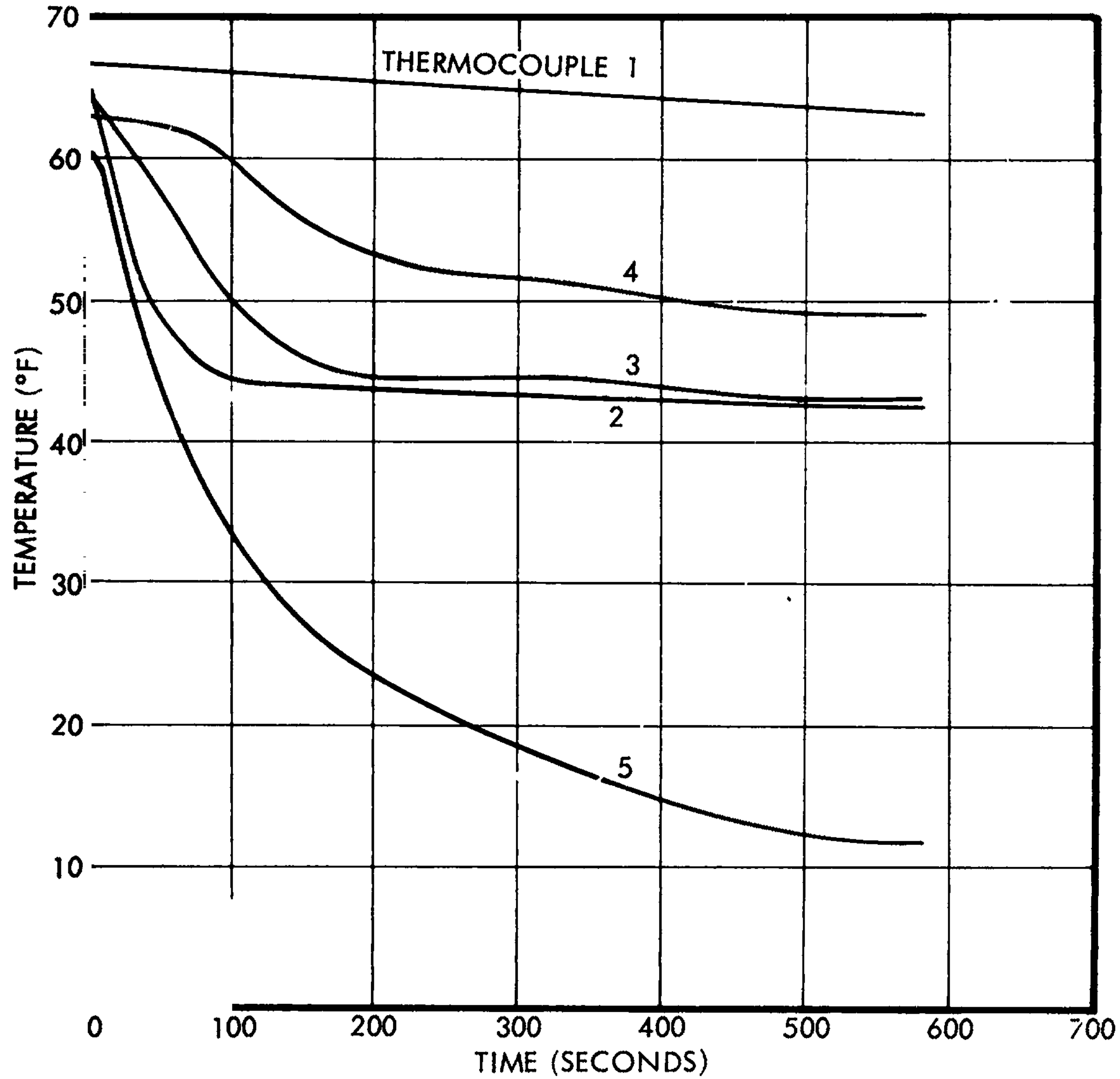


Figure 74. Transient Temperature Profiles Ambient Temperature Start

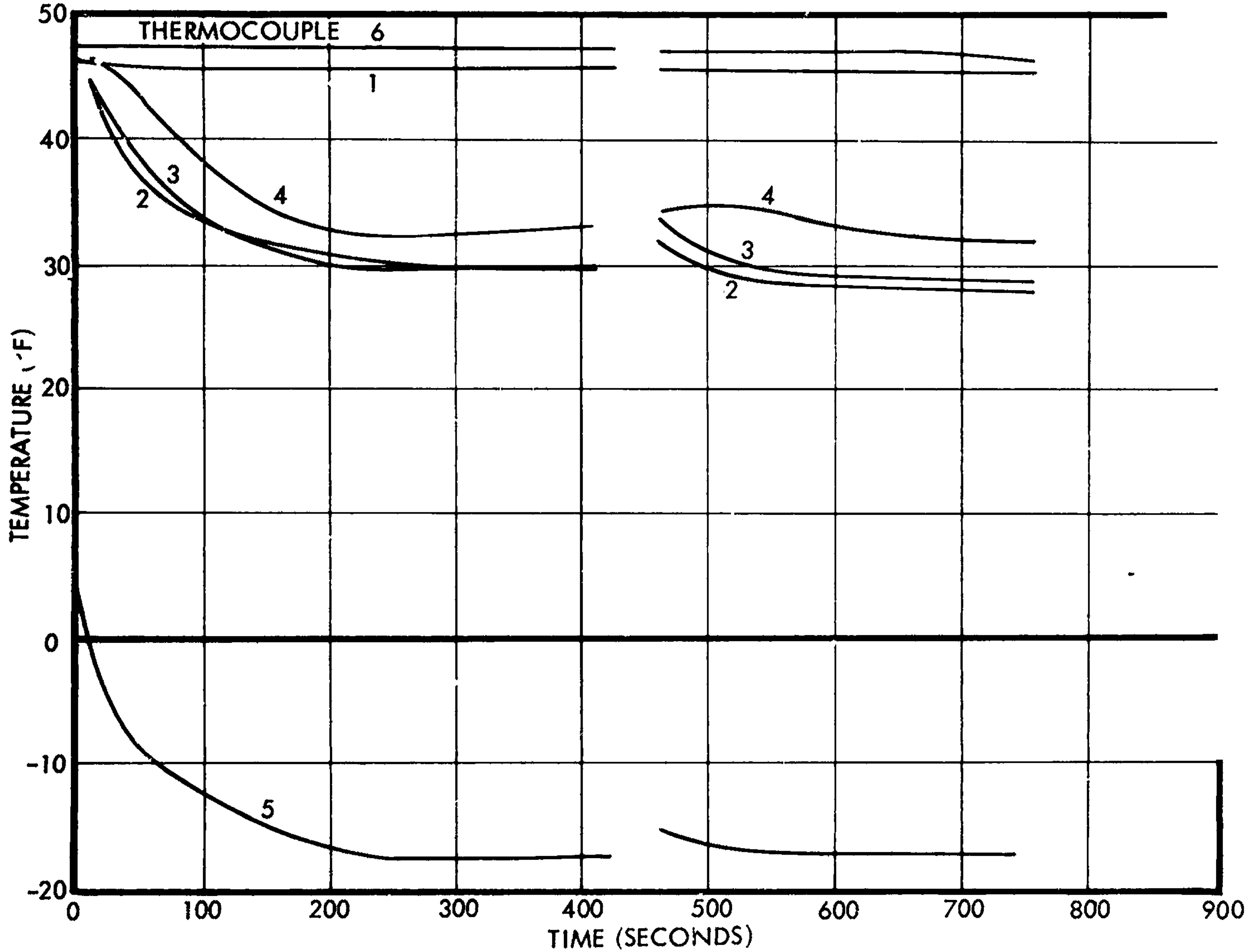


Figure 75. Transient Temperature Profiles Medium Temperature Start

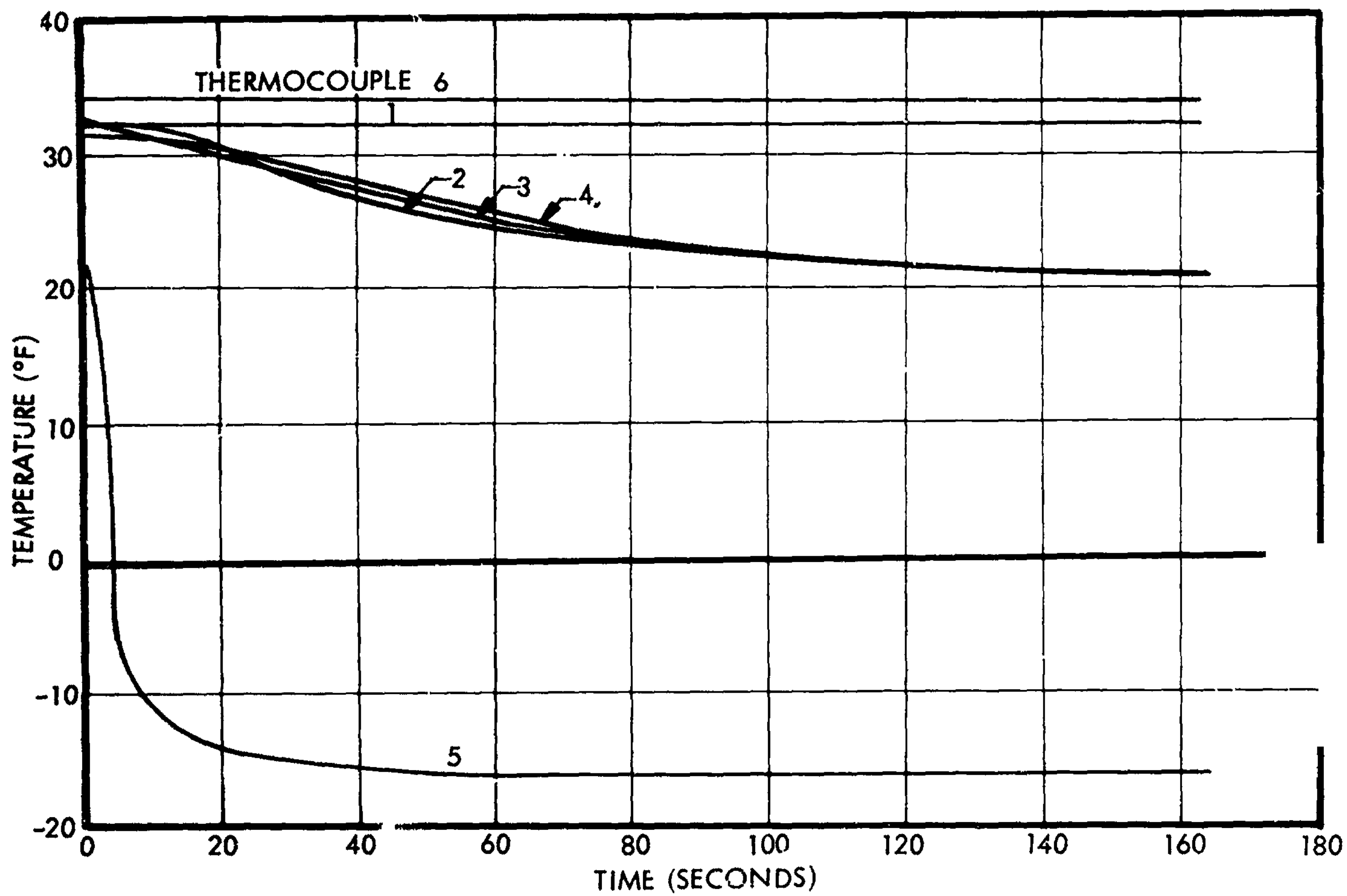


Figure 76. Transient Temperature Profiles, Low Temperature Start

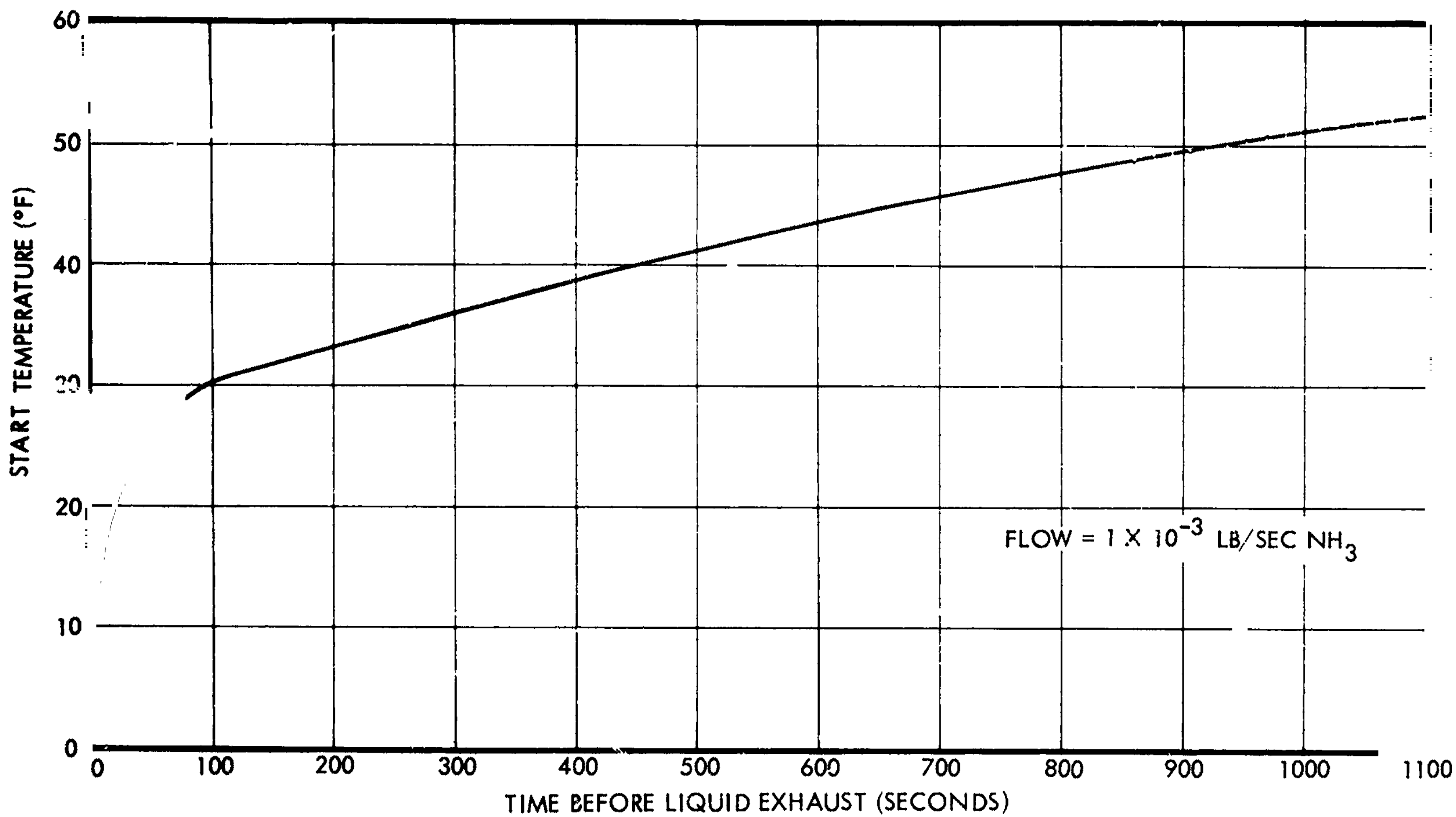


Figure 77. Maximum Flow-Time Limitation

8. CONCLUSIONS AND RECOMMENDATICNS

The results of the program successfully demonstrated the feasibility of using a simple, pneumatically-regulated, ammonia feed system for propulsion applications aboard zero-gravity spacecraft. The experimentally-verified simplicity and performance of the system closely-approximate the characteristics of conventional "cold" gas feed systems at a similar stage of development. The system appears to be sufficiently well-developed to be considered for entry into a long-duration demonstration test and an environmental qualification program. Additional development efforts could be devoted toward incorporation of more sophisticated fabrication and assembly techniques.

9. NEW TECHNOLOGY

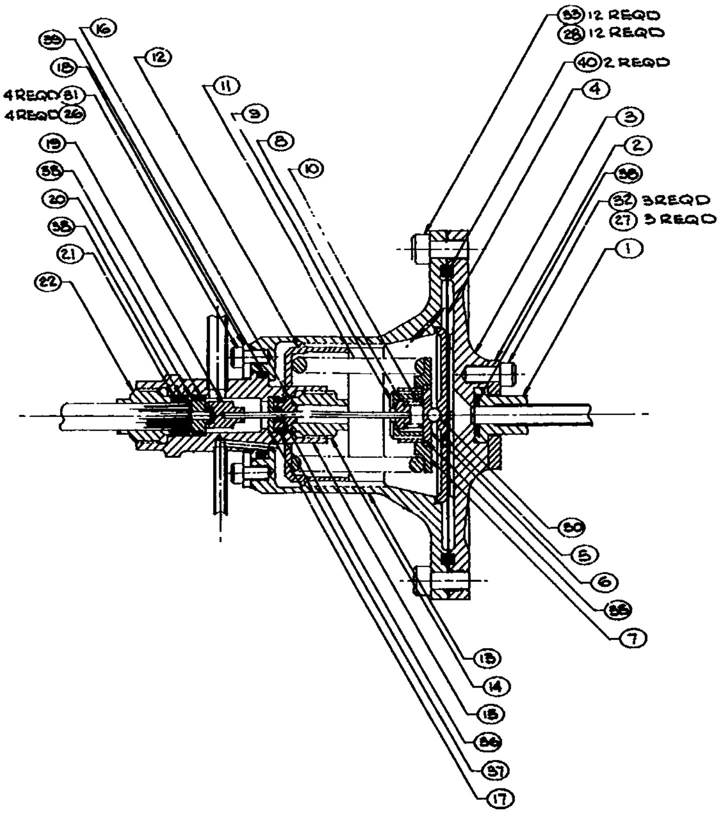
The technology used during the progress of this program was delineated in the proposal submitted prior to initiation of the program. There was no new technology generated or required for the completion of this program.

10. BIBLIOGRAPHY

1. AFAPL-TR-68-14, "Attitude Control and Stationkeeping Program," Final Report, March 1968.
2. Chemical Engineering, Volume 1, Fluid Flow Heat Transfer and Mass Transfer, J. M. Coulson and J. F. Richardson, p. 177, Rev. 1955, McGraw-Hill, Inc., New York.

APPENDIX I. FLIGHT REGULATOR DRAWING LIST

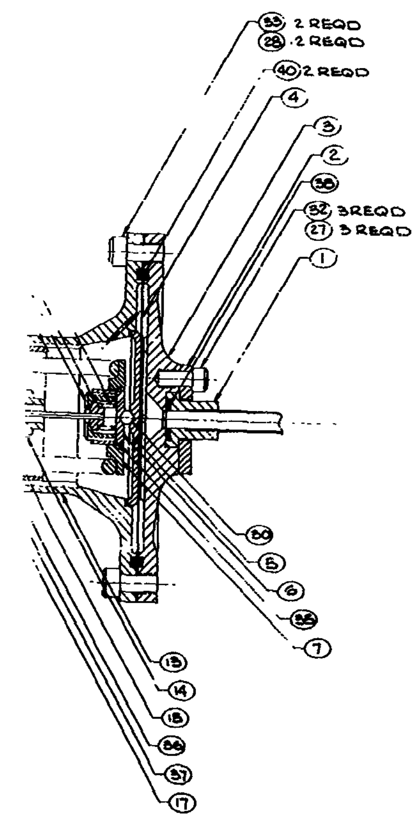
DRAWING NUMBER	TITLE
SK4727-69-243	Regulator, Ammonia Thruster
227	Fitting
228	Retainer
229	Plate, End
190	Diaphragm
230	Plate, Diaphragm
231	Plate, Spring
232	Cup, Spring
195	Stop
193	Retainer, Spring
194	Spring, Compression
233	Nut, Adjusting
234	Body
235	Nut
236	Housing, Stem
237	Sleeve
238	Washer
239	Ring, Clamp
202	Poppet
241	Seat
242	Header
204	Nut



1. IDENTIFICATION MARKING PER PR 12-1
TYPE______CLASS______PART NUMBER______

NOTES: UNLESS OTHERWISE SPECIFIED

FOLDOUT FRAME



Qty	Code	Part No.	Description		Item
2	83259	2-038	O RING	[illegible]	[illegible]
1		2-0[illegible]			[illegible]
3		2-0[illegible]			[illegible]
1		2-009			[illegible]
	83259	2-002	O RING	[illegible]	[illegible]
		25-50	[illegible]		[illegible]
					[illegible]
2		[illegible]	SCREW		[illegible]
3		[illegible]	SCREW		[illegible]
4		[illegible]	SCREW		[illegible]
		[illegible]	BALL		[illegible]
					[illegible]
2		[illegible]	WASHER		[illegible]
3		[illegible]	WASHER		[illegible]
4		[illegible]	WASHER		[illegible]
					[illegible]
					[illegible]
					[illegible]
		SK4727-69-[illegible]	NUT		[illegible]
1		[illegible]	HEADER		[illegible]
		[illegible]	SEAT		[illegible]
		[illegible]	POPPET		[illegible]
		[illegible]	RING		[illegible]
		[illegible]	WASHER		[illegible]
		[illegible]	SLEEVE		[illegible]
		[illegible]	HOUSING		[illegible]
		[illegible]	NUT		[illegible]
1		-234	BODY		[illegible]
		[illegible]	NUT		[illegible]
1		[illegible]	SPRING		[illegible]
		[illegible]	SPRING		[illegible]
		[illegible]	RETAINER		[illegible]
		[illegible]	STOP		[illegible]
		[illegible]	CUP		[illegible]
		[illegible]	PLATE		[illegible]
		[illegible]	PLATE		[illegible]
		[illegible]	DIAPHRAGM		[illegible]
		229	PLATE		[illegible]
1		228	RETAINER		[illegible]
1		SK4727-69-227	FITTING		[illegible]

PARTS LIST

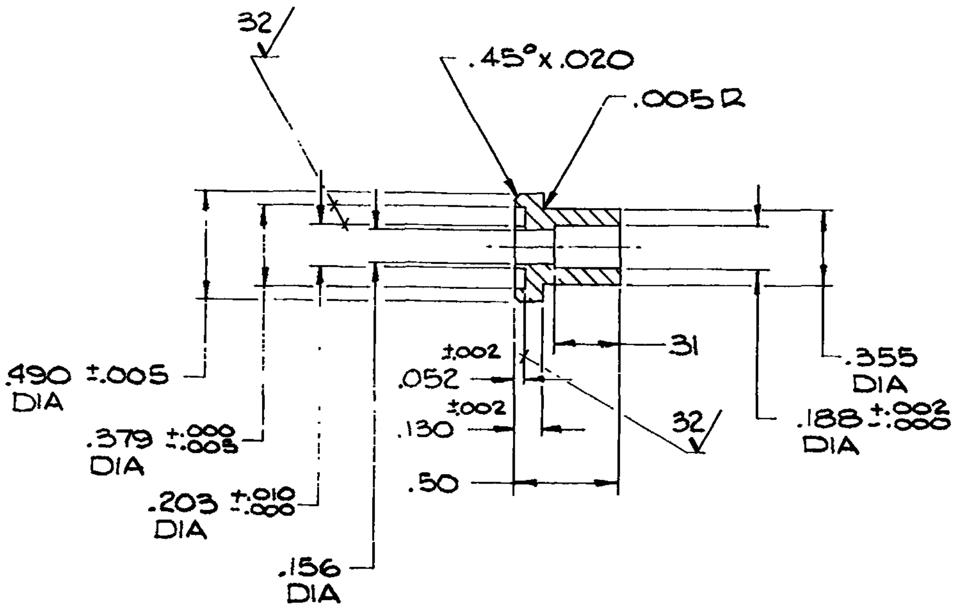
TRW

REGULATOR,
AMMONIA THRUSTER

E 11982 SK4727-69-243

SK4727-69-243

FOLDOUT FRAME



-2 DETAIL

1		-3	TUE
1		-2	FIT
-1	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENC DESC

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ±.010, .XX ±.03, .X ±.1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ±0°30', FORMED ±2°, CHAMFERS ±5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 -.0005
.0145	.125	+.004 -.001
.126	.250	+.005 -.001
.251	.500	+.006 -.001
.501	.750	+.008 -.001
.751	1.000	+.010 -.001
1.001	2.000	+.012 -.001
OVER	2.000	+.015 -.005

CONTRAC
DRAWN N.J.
CHECKED
STRUCTU
MAT'L & PROCESS ENGR
SUPERVI
OTHE APPROV

2. TIG WELD PRIOR TO FINISH MACHINING.

1. IDENTIFICATION MARKING PER PR 12-1
TYPE ________ CLASS ________
PART NUMBER ________

NOTES: UNLESS OTHERWISE SPECIFIED

USED ON	NEXT ASSY	NEXT ASSY QTY REQD
		1
APPLICATION		

PR 12-1

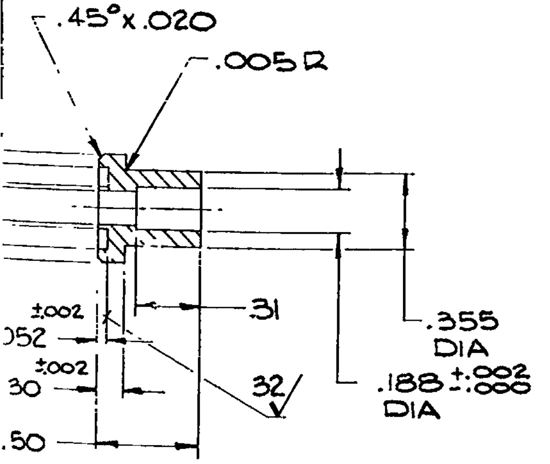
APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

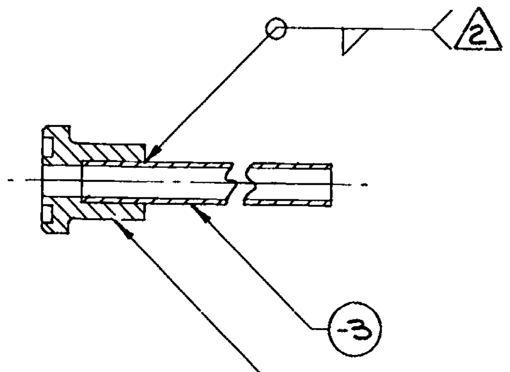
1/60 DIETERICH-POST CLEARPRINT 1000

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



-2 DETAIL



-1 ASSY

1		-3	TUBE	.187 DIA X .035 WALL X 30.0 LG 6061-T6 AL ALY TUBE				
1		-2	FITTING	6061-T6 AL ALY BAR				
-1	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC.	REF DES	ITEM NO.	

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

NEXT ASSY / QTY REQD

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN	N.J. DAVENPORT	11-25-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[illegible signature]	12-2-69
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP

ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

FITTING

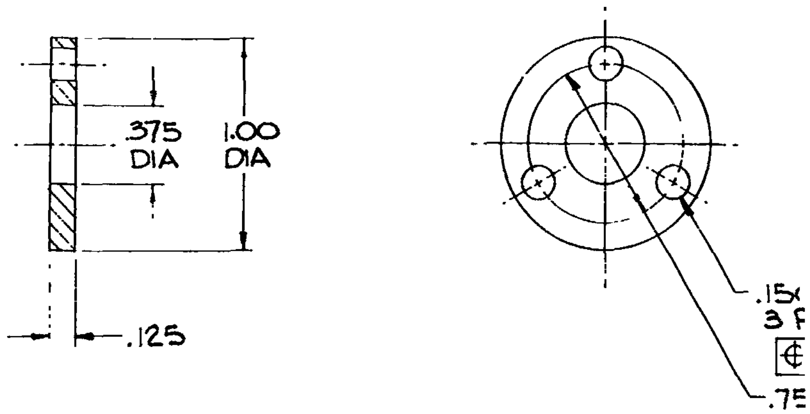
SIZE	CODE IDENT NO.	
C	11982	SK4727-69-227

SCALE 2/1 SHEET 1 OF 1

SYSTEMS 3406 REV 12-66

SK4727-69-227

FOLDOUT FRAME 2



1. IDENTIFICATION MARKING PER PR 12-1
TYPE ______ CLASS ______
PART NUMBER ______

NOTES: UNLESS OTHERWISE SPECIFIED

		1
USED ON	NEXT ASSY	NEXT ASSY QTY REQD
APPLICATION		

				CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
					-1	RETAINE

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

	PR 12-1
APPLICABLE SPECIFICATIONS	

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT

CONTRACT NO.

DRAWN N.J. DAVE

CHECKED

STRUCTURES

MATL & PROCESS

ENGR

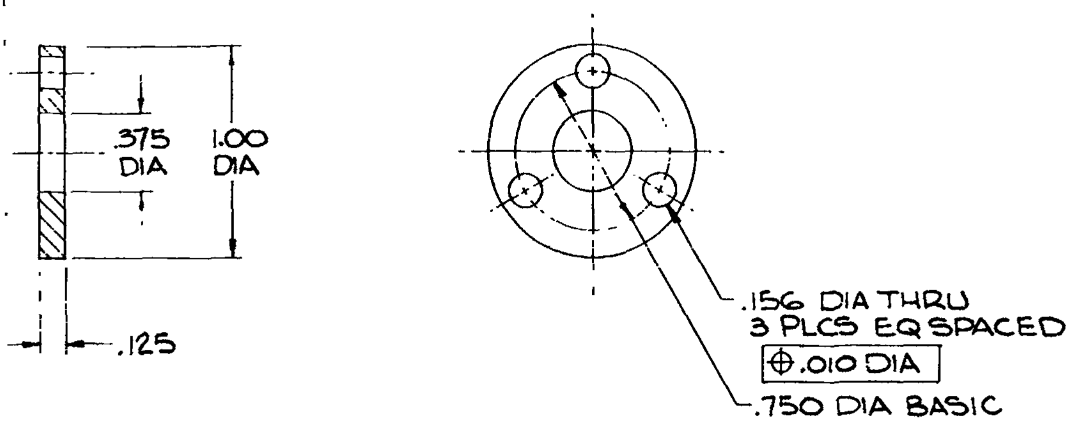
SUPERVISOR

OTHER APPROVALS

1/00 DIETERICH-POST CLEARPRINT 1000

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



SK4727-69-228

				CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC.	REF DES	ITEM NO.
					-1	RETAINER	6061-T6 AL ALY			

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

NEXT ASSY: PR 12-1 — QTY REQD: 1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.		
DRAWN	N. J. DAVENPORT	11-25-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[illegible signature]	12-2-69
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

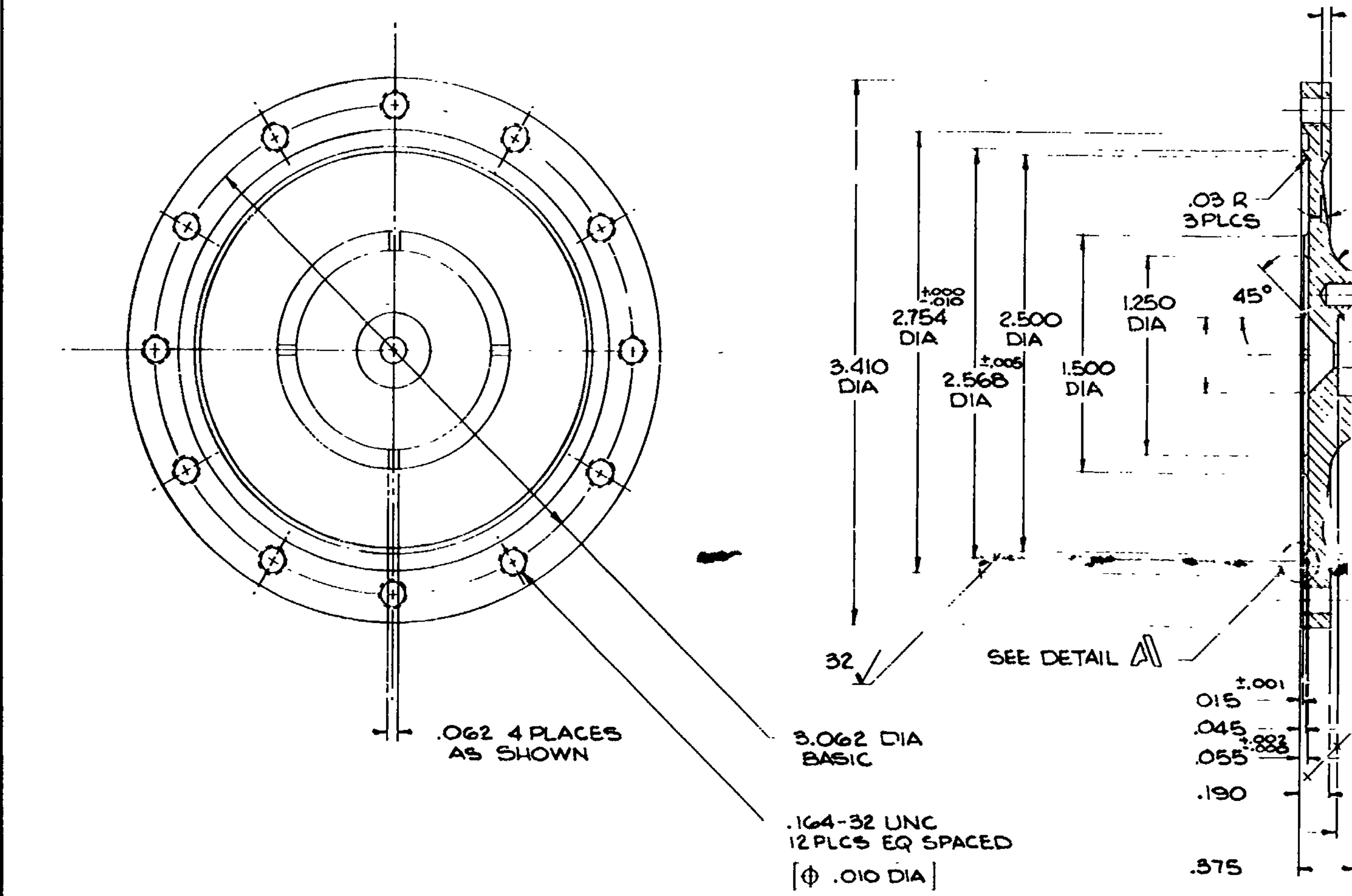
RETAINER

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-228

SCALE 2/1 — SHEET 1 OF 1

SYSTEMS 3406 REV 12-68

FOLDOUT FRAME 2

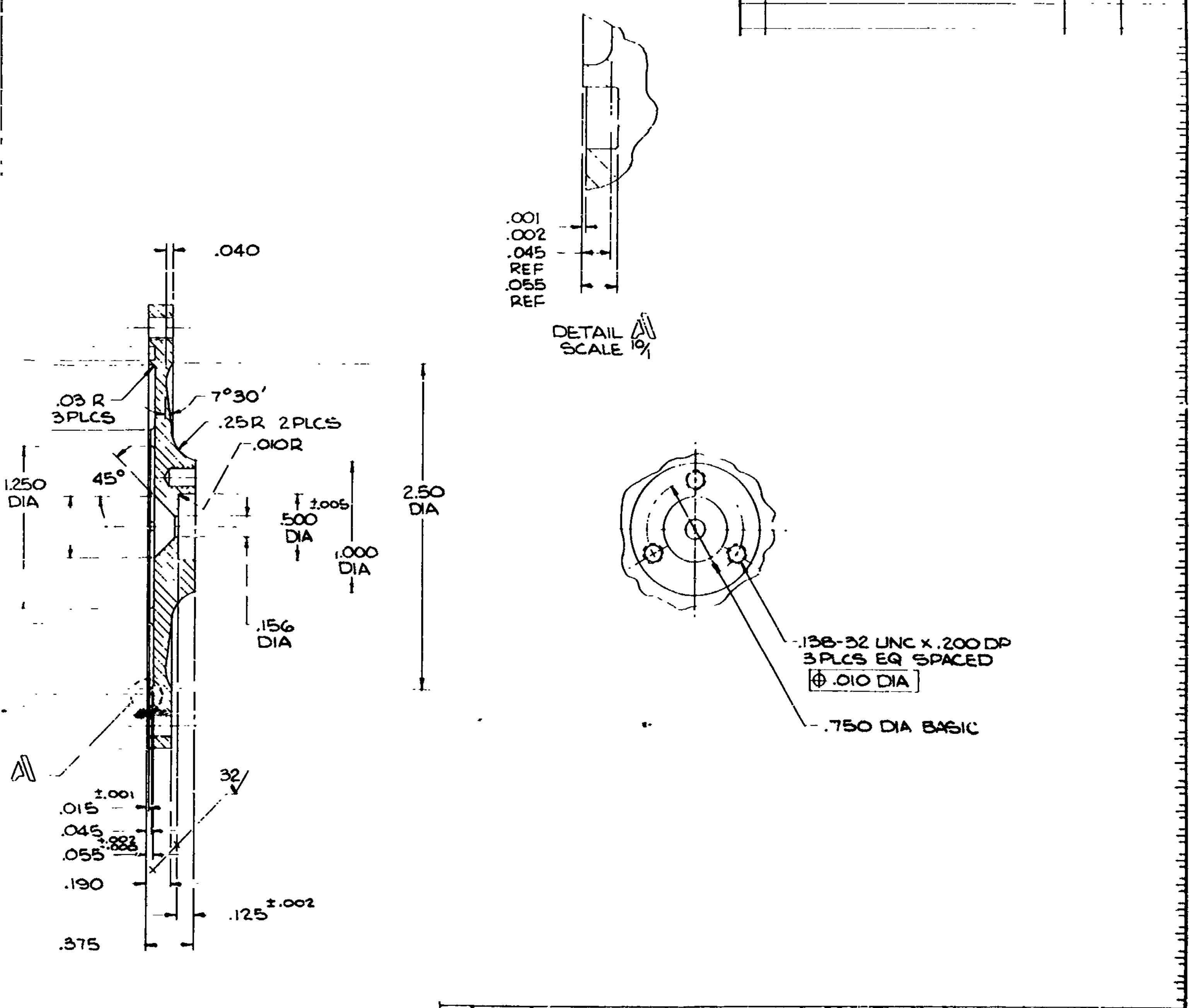


1. IDENTIFICATION MARKING PER PP 2-1
TYPE ___ CLASS ___ PART NUMBER ___

NOTES: UNLESS OTHERWISE SPECIFIED

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC	REF DES	ITEM NO.
	-1	PLATE	6061-T6 AL ALLOY BAR OR PLATE			

PARTS LIST

QTY REQD PER ASSY
CONFIGURATION

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS
THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

USED ON | NEXT ASSY | NEXT ASSY QTY REQD
APPLICATION

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL STD-100
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE ✓
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1
TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

DO NOT SCALE DRAWING
CONTRACT NO.
DRAWN N J DAVENPORT 11-25-69
CHECKED
STRUCTURES
MATL & PROCESS
ENGR 12-2-69
SUPERVISOR
OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

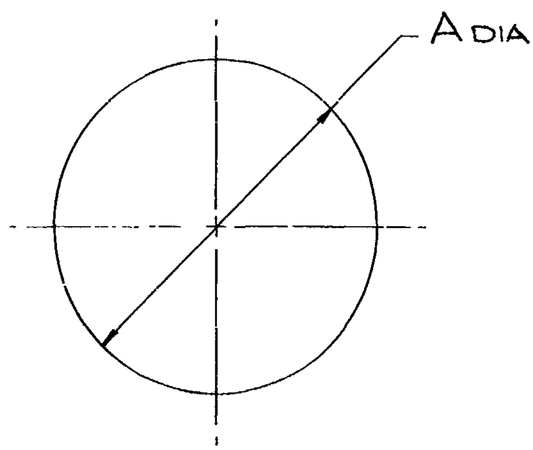
PLATE, END

SIZE D | CODE IDENT NO. 11982 | SK4727-69-229

SCALE 2/1 | SHEET 1 OF 1

SK4727-69-229

FOLDOUT FRAME 2



DASH NO.	A DIA
-1	3.125
-2	3.125
-3	3.125
-4	3.125
-5	2.869

CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMI D
	-5	DIAF
	-4	DIAF
	-3	
	-2	
	-1	DIAP

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

1. IDENTIFICATION MARKNG PER PR 12-1
TYPE ______ CLASS ______
PART NUMBER ______

NOTES: UNLESS OTHERWISE SPECIFIED

NEXT ASSY	USED ON	QTY REQD
SK4727-69-205		1

APPLICATION

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE ✓
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA

FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT

CONTRACT NO.

DRAWN DAVEN

CHECKED

STRUCTURES

MATL & PROCESS

ENGR

SUPERVISOR

OTHER APPROVALS

6/68 DIETERICH-POST CLEARPRINT 1000

FOLDOUT FRAME /

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	ADDED -5 & TAB BLOCK 'A' DIA WAS 3.125 DIA	11-25-69	

A DIA

SK4727-69-190 A

					CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC	REF DES	ITEM NO.
						-5	DIAPHRAGM	.003 SHIM STOCK CRES 302 ANNEALED			
						-4	DIAPHRAGM	.006 SHIM STOCK CRES 321 ANNEALED			
						-3		.005 SHIM STOCK CRES 321 ANNEALED			
						-2		.004 SHIM STOCK CRES 321 ANNEALED			
						-1	DIAPHRAGM	.003 SHIM STOCK CRES 302 ANNEALED			

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE ✓
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN	DAVENPORT	10-6-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[signature]	10-10-69
SUPERVISOR		

OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

DIAPHRAGM

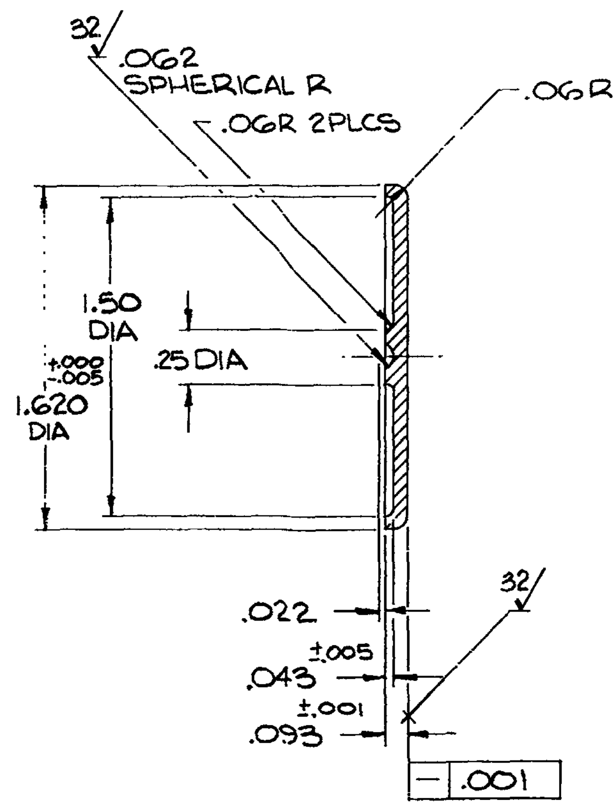
SIZE	CODE IDENT NO.	
C	11982	SK4727-69-190

SCALE NONE SHEET 1 OF 1

SYSTEMS 1462C REV. 3-68

FOLDOUT FRAME 2

LTR



					-1	PLATE
				CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT

CONTRACT NO.

DRAWN N.J. DAVE

CHECKED

STRUCTURES

MATL & PROCESS

ENGR

SUPERVISOR

OTHER APPROVALS

USED ON	NEXT ASSY	NEXT ASSY QTY REQD
		1
APPLICATION		

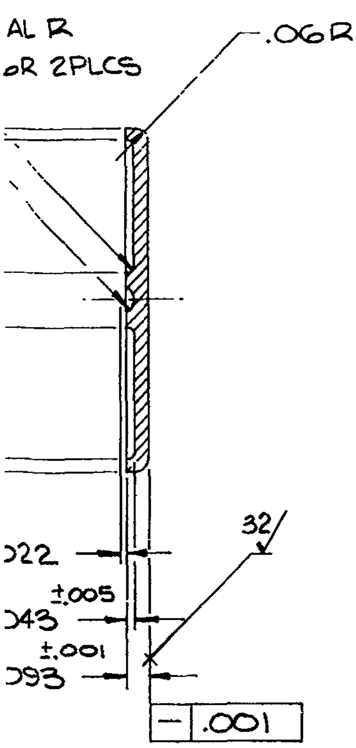
1. IDENTIFICATION MARKING PER PR 12-1
TYPE ____ CLASS ____
PART NUMBER ____

NOTES: UNLESS OTHERWISE SPECIFIED

1/60 DIETERICH-POST CLEARPRINT 1000

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



SK4727-69-230

ITEM NO.	REF DES	SPEC.	MATERIAL	NOMENCLATURE OR DESCRIPTION	PART OR IDENTIFYING NO.	CODE IDENT NO.
			CRES 304	PLATE	-1	

PARTS LIST

QTY REQD PER ASSY CONFIGURATION

NEXT ASSY	QTY REQD
	1

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125/
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ±.010, .XX ±.03, .X ±.1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN	N.J. DAVENPORT	11-25-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[signature]	12-2-69
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

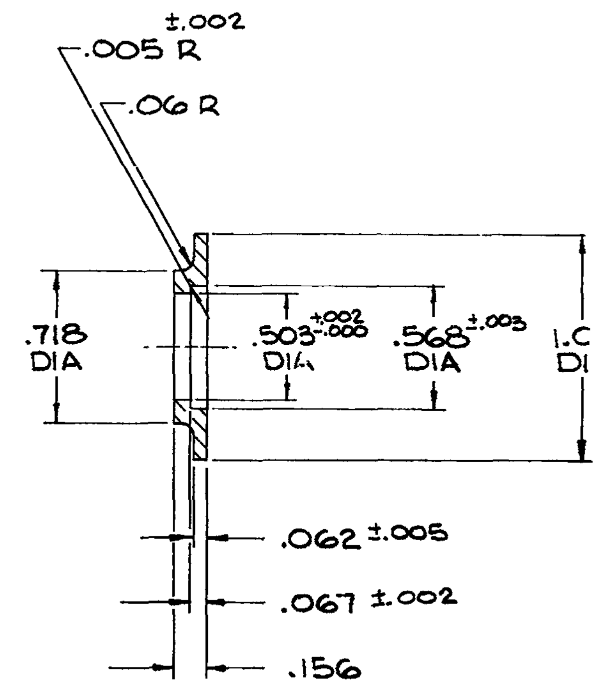
PLATE, DIAPHRAGM

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-230

SCALE 2/1 SHEET 1 OF 1

SYSTEMS 3486 REV. 12-68

FOLDOUT FRAME 2



					-1	PLATE
				CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE DESCRIPTIO

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TRE T

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT

CONTRACT NO.

DRAWN N. J. DAV

CHECKED

STRUCTURES

MATL & PROCESS

ENGR

SUPERVISOR

OTHER APPROVALS

		1
USED ON	NEXT ASSY	NEXT ASSY QTY REQD
APPLICATION		

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

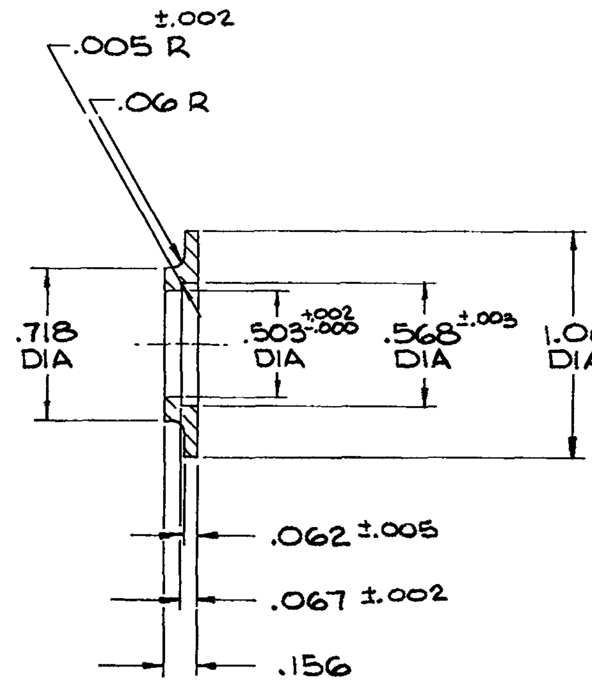
1. IDENTIFICATION MARKING PER PR 12-1
TYPE______CLASS____
PART NUMBER______

NOTES: UNLESS OTHERWISE SPECIFIED

1/60 DIETERICH-POST CLEARPRINT 1000

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPPOVED



SK4727-69-231

		-1	PLATE	6061-T6 AL ALY			
CODE IDENT NO.		PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC.	REF DES	ITEM NO.

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.		
DRAWN	N. J. DAVENPORT	11-25-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[signature]	12-2-69
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

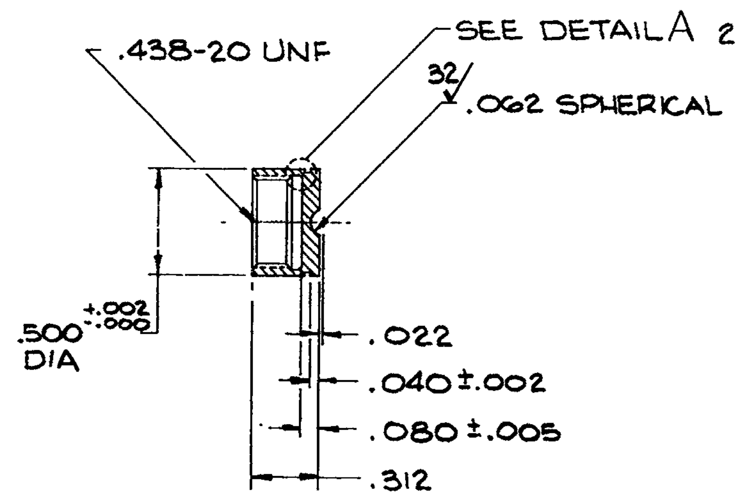
PLATE, SPRING

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-231

SCALE 2/1 SHEET 1 OF 1

SYSTEMS 3406 REV. 12-68

FOLDOUT FRAME 2



					-1	CUP
				CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SC

CONTRACT NO.

DRAWN N.J. DAVEN

CHECKED

STRUCTURES

MATL & PROCESS

ENGR

SUPERVISOR

OTHER APPROVALS

LTR

1 | PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

NEXT ASSY	USED ON	NEXT ASSY QTY REQD
APPLICATION		

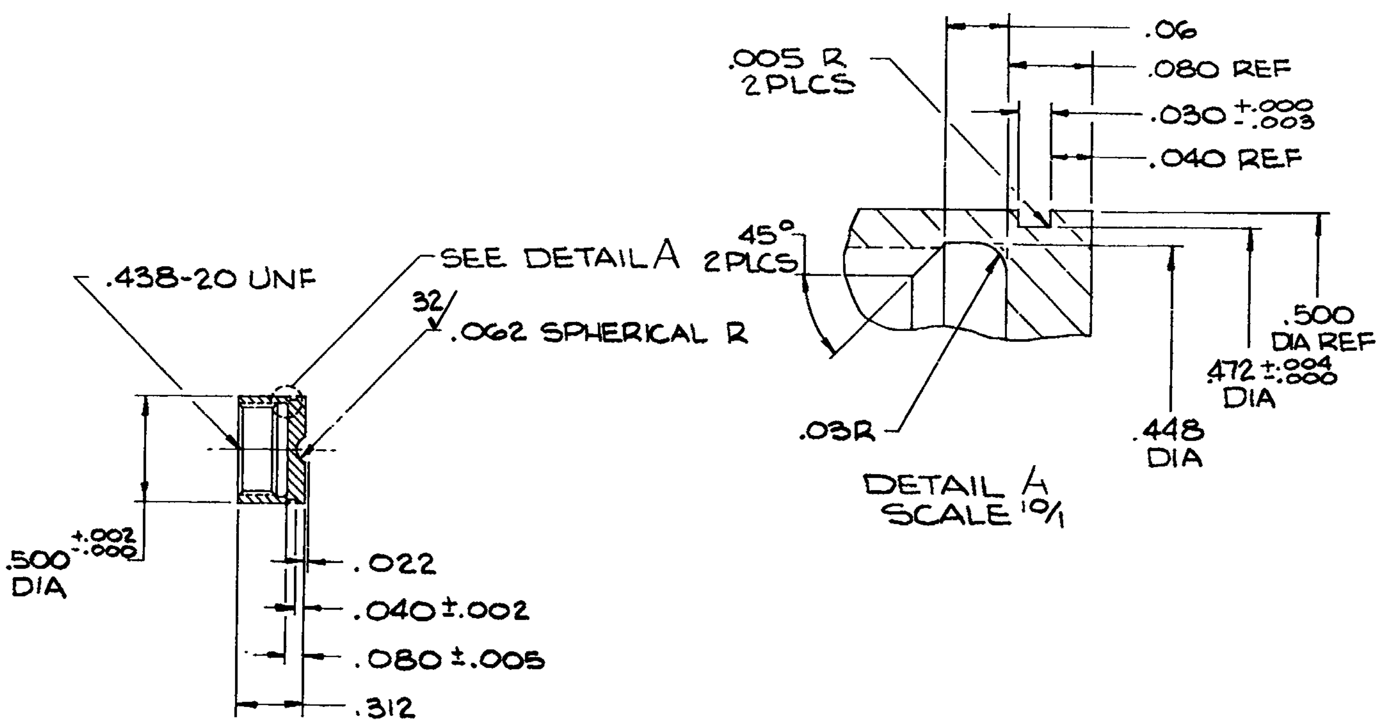
1. IDENTIFICATION MARKING PER PR 12-1
TYPE ________ CLASS ________
PART NUMBER ________

NOTES: UNLESS OTHERWISE SPECIFIED

1/68 DIETERICH-POST CLEARPRINT 1000

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



SK472769-232

			CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC.	REF DES	ITEM NO.
				-1	CUP	CRES 304			

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

1	PR 12-1
NEXT ASSY QTY REQD	APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.		
DRAWN	N.J. DAVENPORT	11-25-68
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[signature]	12-2-69
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

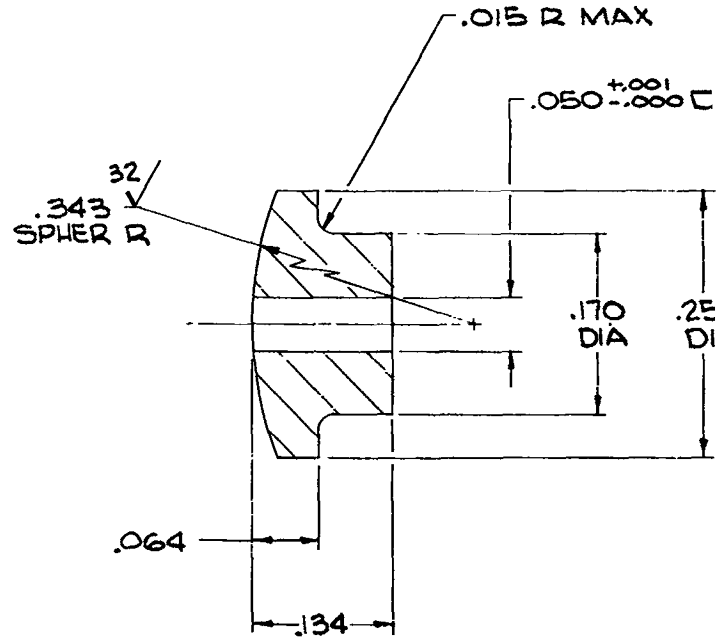
TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

CUP, SPRING

SIZE	CODE IDENT NO.	
C	11982	SK472769-232
SCALE 2/1		SHEET 1 OF 1

SYSTEMS 3400 REV. 12-68

FOLDOUT FRAME 2



	-1	S	
CODE IDENT NO.	PART OR IDENTIFYING NO.		

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 -.0005
.0145	.125	+.004 -.001
.126	.250	+.005 -.001
.251	.500	+.006 -.001
.501	.750	+.008 -.001
.751	1.000	+.010 -.001
1.001	2.000	+.012 -.001
OVER	2.000	+.015 -.005

DO
CONTRACT
DRAWN DA
CHECKED
STRUCTURES
MATL & PROCESS
ENGR
SUPERVISOR
OTHER APPROVALS

1. IDENTIFICATION MARKNG PER PR 12-1
TYPE ______ CLASS ______
PART NUMBER ______

USED ON	NEXT ASSY	NEXT ASSY QTY REQD
	SK4727-69-198	1

APPLICATION

PR 12-1

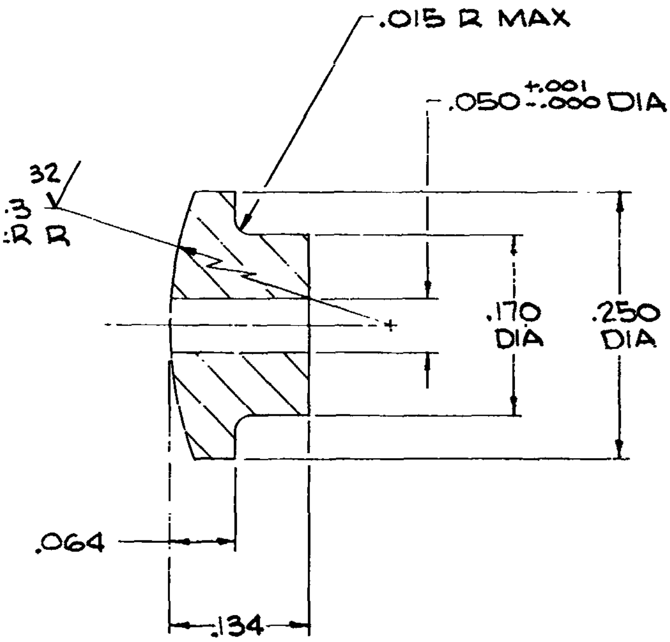
APPLICABLE SPECIFICATIONS
THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

NOTES: UNLESS OTHERWISE SPECIFIED

6/68 DIETERICH-POST CLEARPRINT 1000

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



SK4727-69-195

ITEM NO.	REF DES	SPEC	MATERIAL	NOMENCLATURE OR DESCRIPTION	PART OR IDENTIFYING NO.	CODE IDENT NO.
			304 CRES BAR	STOP	-1	

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

PR 12 1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 -.0005
.0145	.125	+.004 -.001
.126	.250	+.005 -.001
.251	.500	+.006 -.001
.501	.750	+.008 -.001
.751	1.000	+.010 -.001
1.001	2.000	+.012 -.001
OVER	2.000	+.015 -.005

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN	DAVENPORT	10-6-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	Hiken. H	10-10-69
SUPERVISOR		

OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

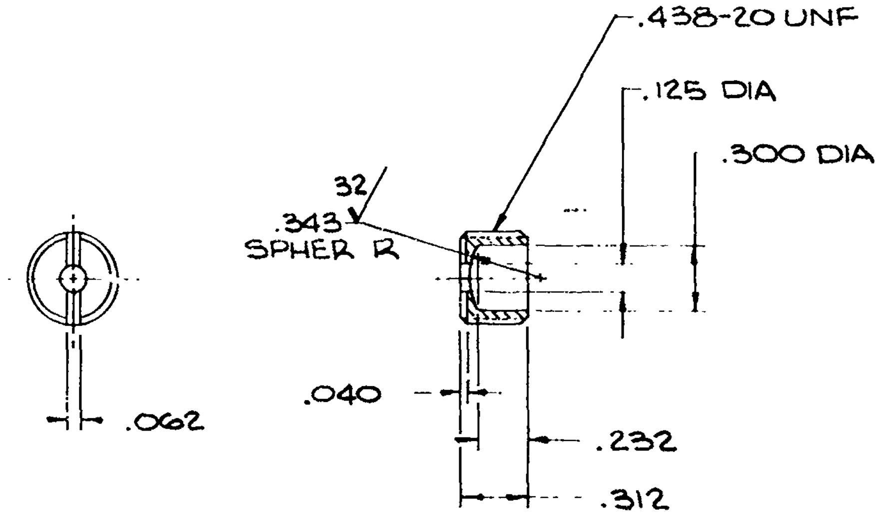
STOP

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-195

SCALE 10/1 | SHEET 1 OF 1

SYSTEMS 1400C REV. 5-68

FOLDOUT FRAME 2



					CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMEN... DE...
						-1	RET...

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

1. IDENTIFICATION MARKNG PER PR 12-1
TYPE ______ CLASS ______
PART NUMBER ______

NOTES: UNLESS OTHERWISE SPECIFIED

USED ON	NEXT ASSY	NEXT ASSY QTY REQD
	SK472769-205	1

APPLICATION

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

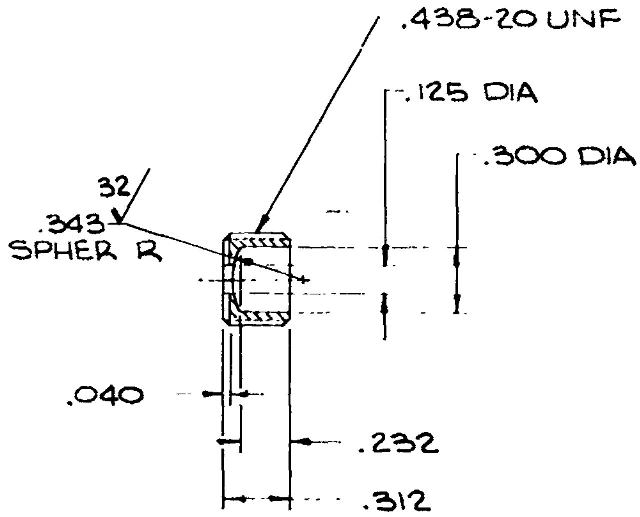
TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT ...
CONTRACT NO.
DRAWN DAVE...
CHECKED
STRUCTURES
MATL & PROCESS
ENGR
SUPERVISOR
OTHER APPROVALS

6/68 DIETERICH-POST CLEARPRINT 1000

FOLDOUT FRAME

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



62

SK472769-193

CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC	REF DES	ITEM NO.
	-1	RETAINER	304 CRES BAR			

PARTS LIST

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

1208 1	PR 12-1

NEXT ASSY QTY REQD

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
[illegible] ± 3°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.[illegible]
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.		
DRAWN	DAVENPORT	10-6-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[illegible]	10 13 69
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

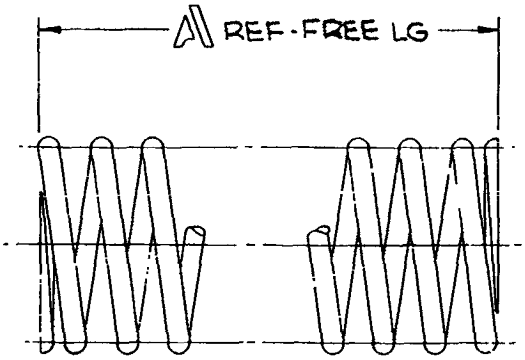
TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

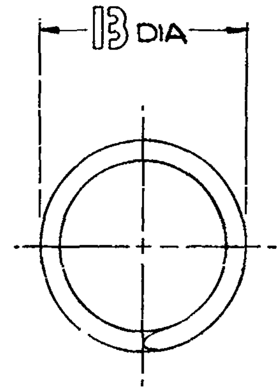
RETAINER, SPRING

SIZE	CODE IDENT NO.	
C	11982	SK472769-193
SCALE 2/1		SHEET 1 OF 1

SYSTEMS 3400 REV. 1-68

FOLDOUT FRAME 2





SPRING DATA	-1	-2
A DIM REF	1.550	.347
B DIA	1.062	.250
TOTAL COILS	6	5
LOAD AT COMPRESSED LENGTH OF	1.048	.200
POUNDS	110	2.6
DIRECTION OF HELIX	RIGHT	
WIRE DIA	.148	.026
MATL	MUSIC WIRE	

5. STRESS RELIEVE AND PRESET AFTER FORMING.
4. SQUARNESS OF ENDS IN FREE POSITION, WITH AXIS WITHIN 3°
3. CLOSED ENDS GROUND 270° MIN.
2. COILS TO BE HELICAL AND CONCENTRIC WITHIN .020 FOR -1, .010 FOR -2.
1. IDENTIFICATION MARKNG PER PR 12-1

TYPE ____ CLASS ____

PART NUMBER ____

NOTES: UNLESS OTHERWISE SPECIFIED

SK4727-69-205		1	
USED ON	NEXT ASSY	NEXT ASSY QTY REQD	
APPLICATION			

CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMEN... DE...
	-2	SPR
	-1	SPR

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE ✓
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.002 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT

CONTRACT NO.

DRAWN DAVEN

CHECKED

STRUCTURES

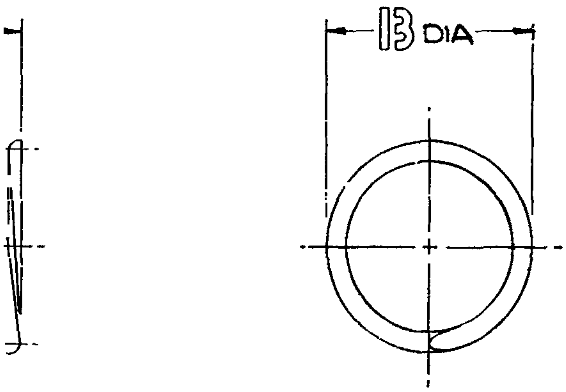
MATL & PROCESS

ENGR Heid.

SUPERVISOR

OTHER APPROVALS

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



SPRING DATA	-1	-2
A DIM REF	1.550	.347
B DIA	1.062	.250
TOTAL COILS	6	5
LOAD AT COMPRESSED LENGTH OF POUNDS	1.048 110	.200 2.6
DIRECTION OF HELIX	RIGHT	
WIRE DIA	.148	.026
MATL	MUSIC WIRE	

SK4727-69-194

					CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC	REF DES	ITEM NO.
						-2	SPRING	SEE TABULATION			
						-1	SPRING	SEE TABULATION			

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE ✓
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 -.0005
.0145	.125	+.004 -.001
.126	.250	+.005 -.001
.251	.500	+.006 -.001
.501	.750	+.008 -.001
.751	1.000	+.010 -.001
1.001	2.000	+.012 -.001
OVER	2.000	+.015 -.005

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN	DAVENPORT	10-6-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[signature]	10-10-69
SUPERVISOR		

OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

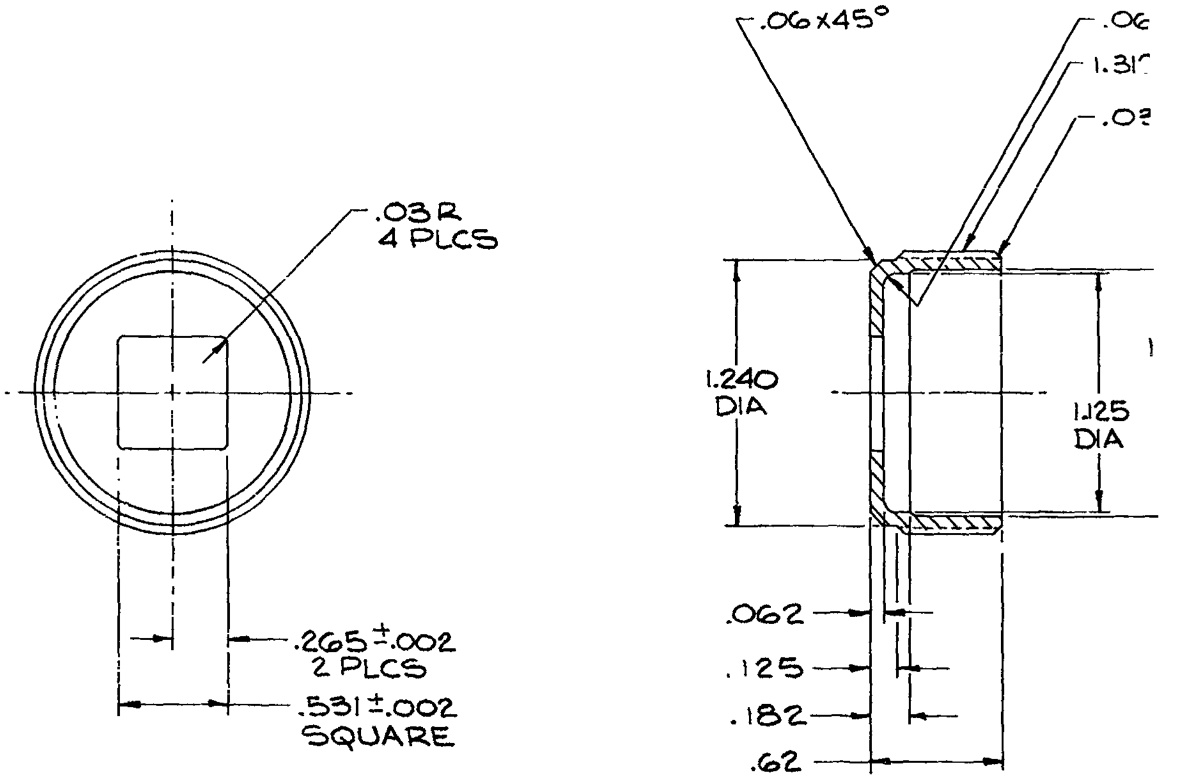
SPRING, COMPRESSION

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-194

SCALE NONE SHEET 1 OF 1

SYSTEMS 1460C REV. 5-68

FOLDOUT FRAME 2



	-1	NUT	
CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLAT DESCRIP	

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO
CONTRACT N
DRAWN N.J.C
CHECKED
STRUCTURES
MATL & PROCESS
ENGR
SUPERVISOR
OTHER APPROVALS

USED ON	NEXT ASSY	NEXT ASSY QTY REQD
		1
APPLICATION		

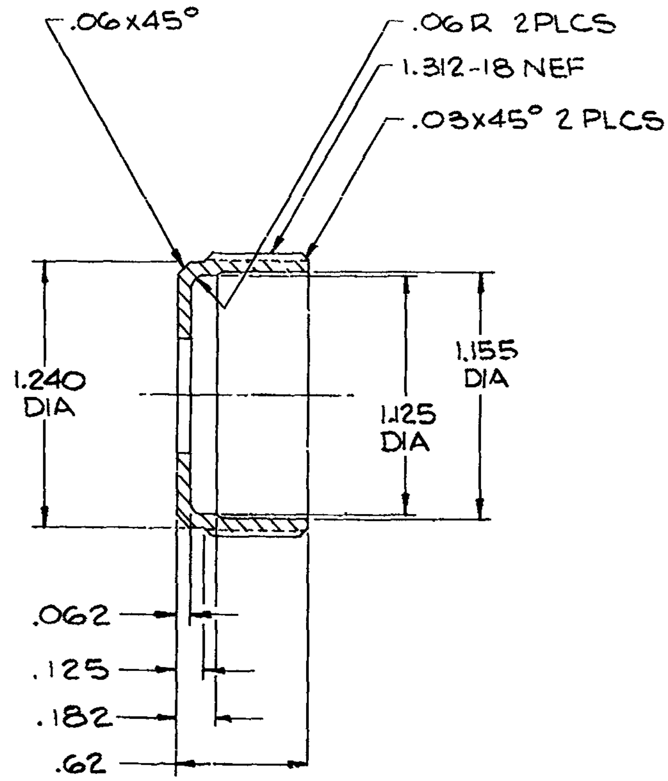
1. IDENTIFICATION MARKING PER PR 12-1
TYPE ________ CLASS ________
PART NUMBER ________

NOTES: UNLESS OTHERWISE SPECIFIED

1/69 DIETZGEN-POST CLEARPRINT 1000

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



SK4727-69-233

CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC.	REF DES	ITEM NO.
	-1	NUT	6061-T6 AL ALY			

PARTS LIST

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

1 PR 12-1

NEXT ASSY QTY REQD

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS-
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.		
DRAWN	N.J. DAVENPORT	11-25-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[signature]	12-2-69
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

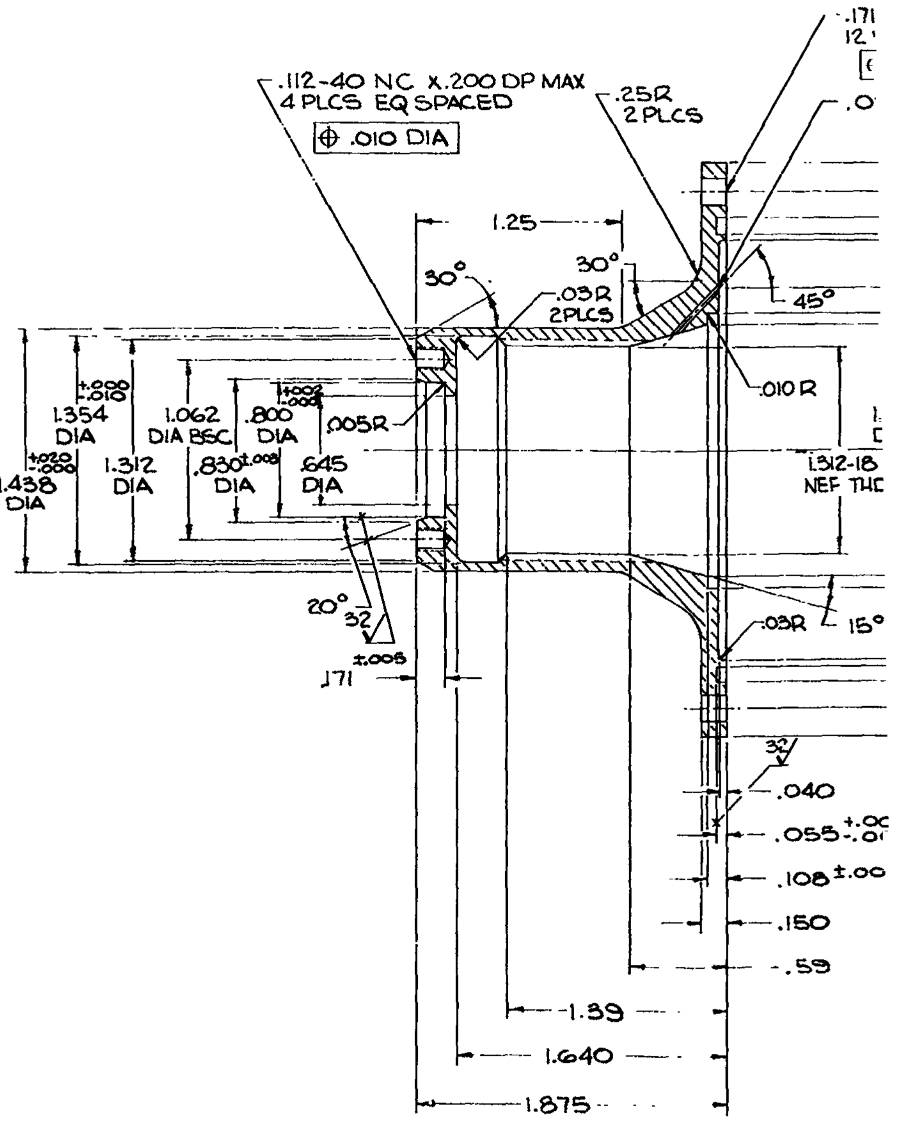
NUT, ADJUSTING

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-233

SCALE 2/1 SHEET 1 OF 1

SYSTEMS 3466 REV. 12-66

FOLDOUT FRAME 2



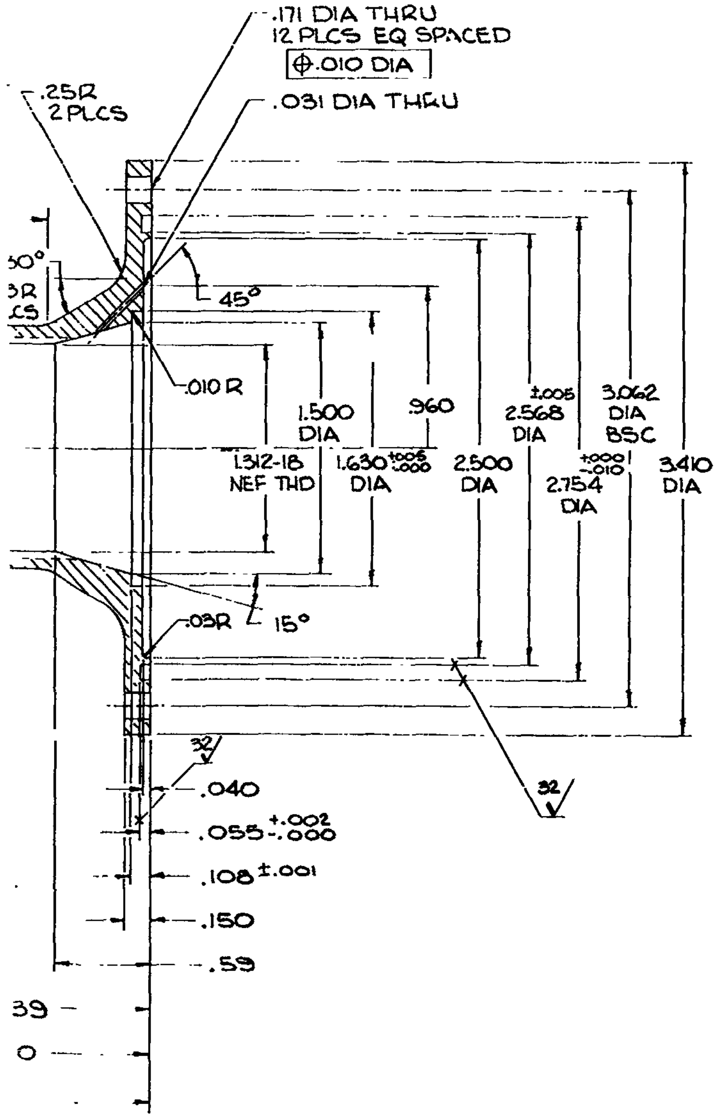
1. IDENTIFICATION MARKING PER PR 12-1
TYPE______CLASS______PART NUMBER______

NOTES: UNLESS OTHERWISE SPECIFIED

USED ON
APPLICATIO

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



		-1	BODY	6061-T6 AL ALLOY BAR		
CODE IDENT NO.	PART OR IDENTIFYING NO.		NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC	REF DES / ITEM NO.

PARTS LIST

QTY REQD PER ASSY
CONFIGURATION

FINISH

HEAT TREAT

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN N.J. DAVENPORT 11-25-69

CHECKED

STRUCTURES

MATL & PROCESS

ENGR 12-2-69

SUPERVISOR

OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

BODY

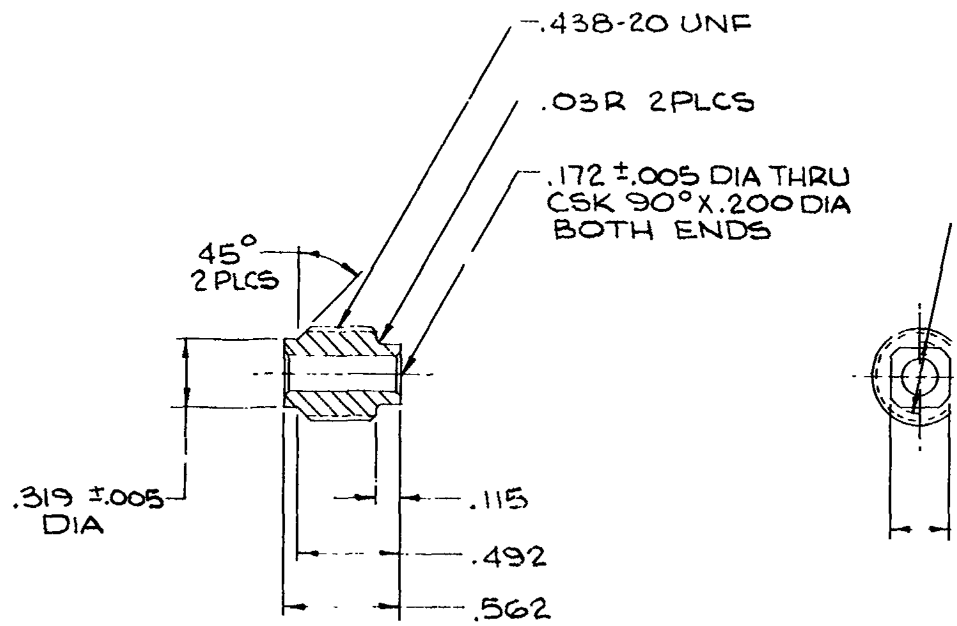
SIZE D | CODE IDENT NO. 11982 | SK4727-69-234

SCALE 2/1 | SHEET 1 OF 1

		1	PR 12-1	APPLICABLE SPECIFICATIONS
USED ON	NEXT ASSY	NEXT ASSY QTY REQD		THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING
APPLICATION				

SK4727-69-234

FOLDOUT FRAME 2



	-1	NUT	
CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATU[RE OR] DESCRIPT[ION]	

QTY REQD PER ASSY
CONFIGURATION

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS-
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO
CONTRACT NO
DRAWN N.J.D
CHECKED
STRUCTURES
MATL & PROCESS ENGR
SUPERVISOR
OTHER APPROVALS

1. IDENTIFICATION MARKING PER PR 12-1
TYPE ______ CLASS ______
PART NUMBER

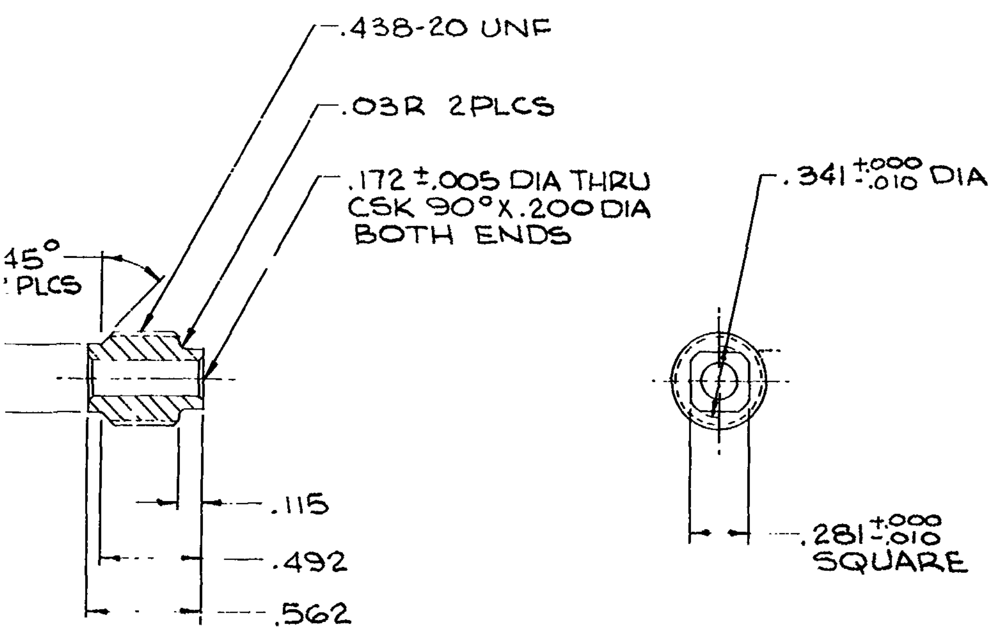
NOTES: UNLESS OTHERWISE SPECIFIED

USED ON	NEXT ASSY	NEXT ASSY QTY REQD
APPLICATION		

1/60 DIETERICH-POST CLEARPRINT 1000

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



SK4727-69-235

				CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC.	REF DES	ITEM NO.
					-1	NUT	6061-T6 AL ALY			

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

PR 12-1

NEXT ASSY | QTY REQD

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN	N.J. DAVENPORT	11-25-68
CHECKED		
STRUCTURES		
MAT'L & PROCESS		
ENGR	[illegible]	12-2-[illegible]
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

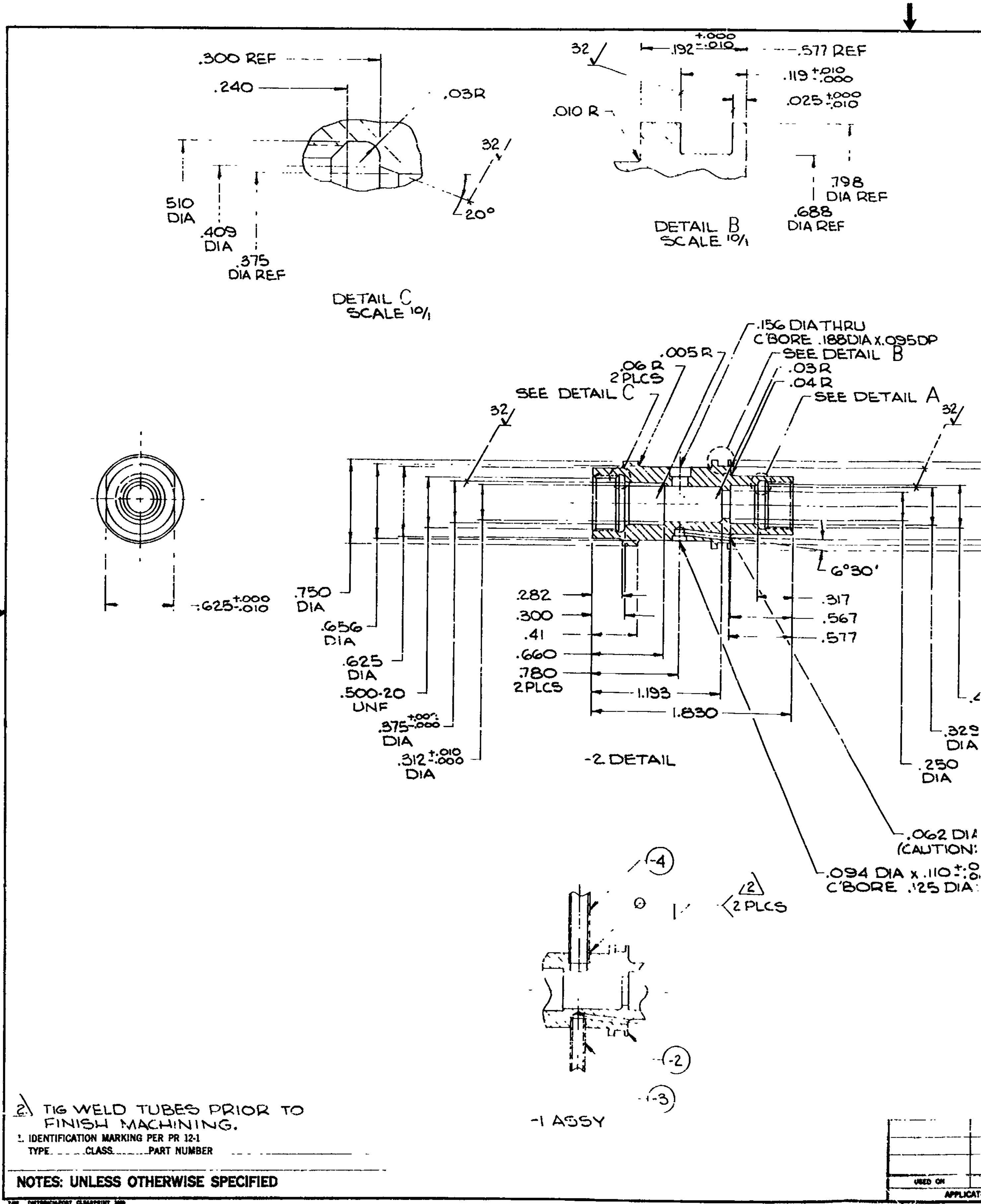
NUT

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-235

SCALE 2/1 | SHEET 1 OF 1

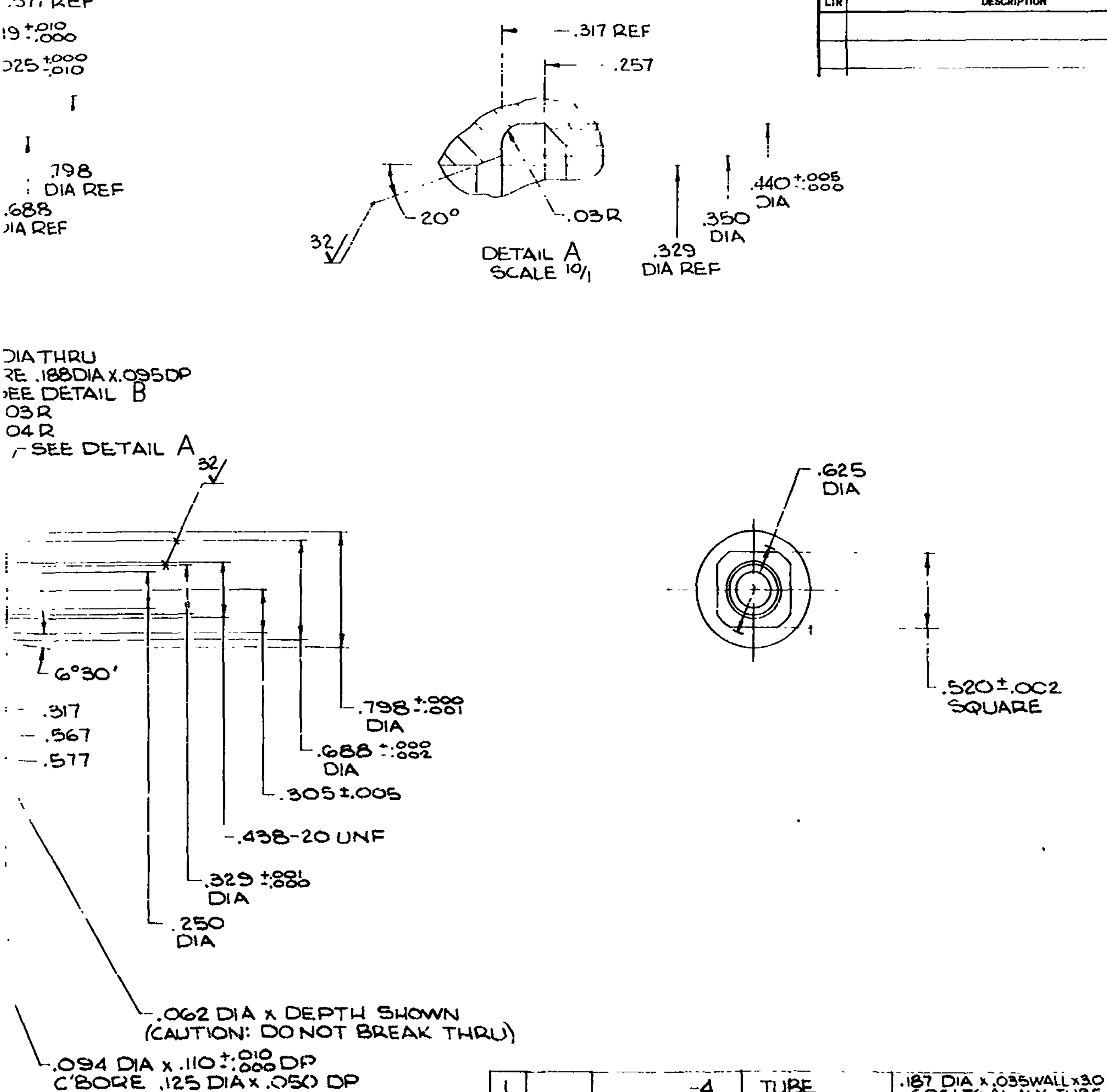
SYSTEMS 3406 REV. 12-68

FOLDOUT FRAME 2



FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



1		-4	TUBE	.187 DIA x .035 WALL x 3.0 LG 6061-T6 AL ALY TUBE			
1		-3	TUBE	.125 DIA x .020 WALL x 3.0 LG 6061-T6 AL ALY TUBE			
1		-2	BODY	6061-T6 AL ALY BAR			
-1	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC	REF DES	ITEM I.D.

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 25
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA

FROM	THRU	TOL.
UNDER	.0140	
.0145	.125	
.126	.250	
.251	.500	
.501	.750	
.751	1.000	
1.001	2.000	
OVER	2.000	

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN N. J. DAVENPORT 1-25-69

CHECKED

STRUCTURES

MAT'L & PROCESS

ENGR 2-2-69

SUPERVISOR

OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

HOUSING, STEM

SIZE D | CODE IDENT NO. 11982 | SK4727-69-236

SCALE 2/1 | SHEET 1 OF 1

PR 12-1

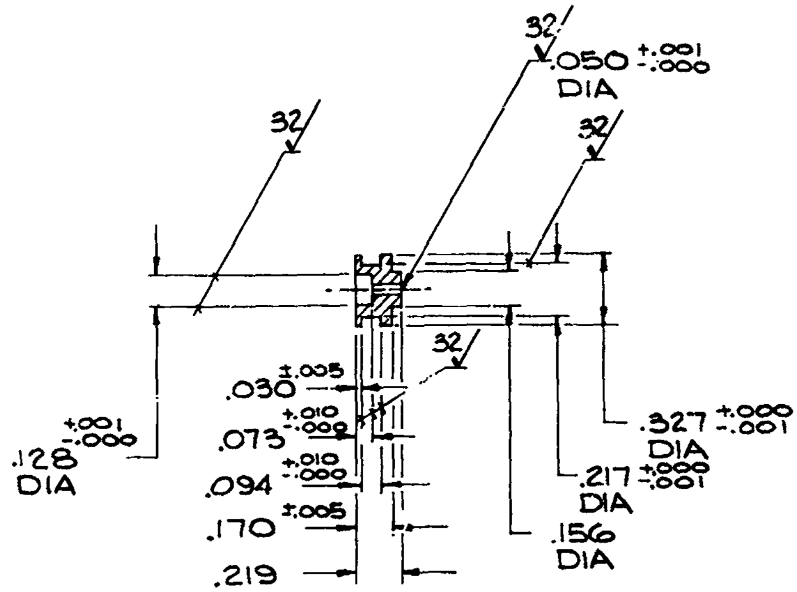
APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

USED ON | NEXT ASSY | APPLICATION

SK4727-69-236

FOLDOUT FRAME 2



-1	SLEE	
CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLAT DESCRIP

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± [illegible]

TOLERANCES - ALL HOLE DIA

FROM	THRU	TOL.
UNDER	.0140	+.0020 -.0005
.0145	.125	+.004 -.001
.126	.250	+.005 -.001
.251	.500	+.006 -.001
.501	.750	+.008 -.001
.751	1.000	+.010 -.001
1.001	2.000	+.012 -.001
OVER	2.000	+.015 -.005

DO

CONTRACT N

DRAWN N.J.D.

CHECKED

STRUCTURE

MATL & PROCESS

ENGR

SUPERVISOR

OTHER APPROVALS

USED ON	NEXT ASSY	NEXT ASSY QTY REQD
		1
APPLICATION		

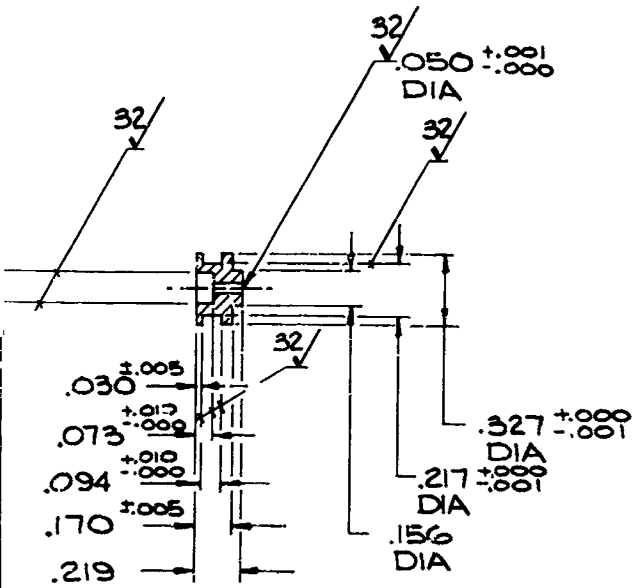
1. IDENTIFICATION MARKING PER PR 12-1
TYPE ____ CLASS ____
PART NUMBER ____

NOTES: UNLESS OTHERWISE SPECIFIED

1/68 DIETZGEN-POST CLEARPRINT 1000

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



SK4727-69-237

				CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC.	REF DES	ITEM NO.
					-1	SLEEVE	CRES 303			

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0146	+.0020 -.0005
.0146	.125	+.004 -.001
.126	.250	+.005 -.001
.251	.500	+.006 -.001
.501	.750	+.008 -.001
.751	1.000	+.010 -.001
1.001	2.000	+.01 -.001
OVER	2.000	+.015 -.001

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN	N.J. DAVENPORT	1-25-69
CHECKED		
STRUCTURES		
MAT'L & PROCESS		
ENGR	[illegible signature]	12-2-69
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

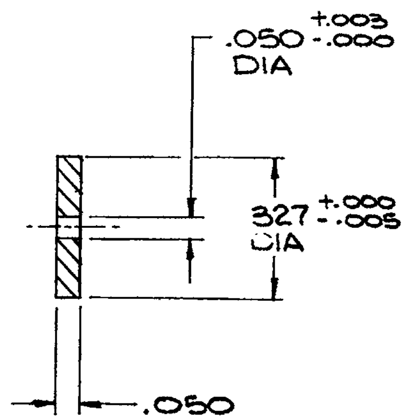
SLEEVE

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-237

SCALE 4/1 SHEET OF

SYSTEMS 3003 REV. 12-66

FOLDOUT FRAME 2



				CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
					-1	WASHER

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 32✓
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA

FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT

CONTRACT NO.

DRAWN N.J. DAV

CHECKED

STRUCTURES

MATL & PROCESS

ENGR. Jamm

SUPERVISOR

OTHER APPROVALS

LT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

1		
NEXT ASSY QTY REQD	USED ON	NEXT ASSY

APPLICATION

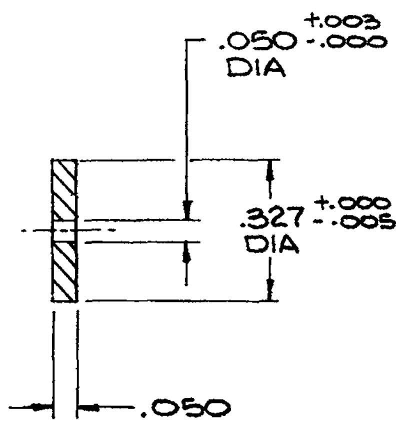
1. IDENTIFICATION MARKING PER PR 12-1
TYPE ________ CLASS ________
PART NUMBER ________

NOTES: UNLESS OTHERWISE SPECIFIED

11/69 DIETZGEN-POST CLEARPRINT 1020

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



SK4727-69-238

			-1	WASHER	6061-T6 AL ALY			
	CODE IDENT NO.	PART OR IDENTIFYING NO.		NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC.	REF DES	ITEM NO.

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 32
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 -.0005
.0145	.125	+.004 -.001
.126	.250	+.005 -.001
.251	.500	+.006 -.001
.501	.750	+.008 -.001
.751	1.000	+.010 -.001
1.001	2.000	+.012 -.001
OVER	2.000	+.01 -.00

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN	N.J. DAVENPORT	11-25-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[signature]	12-2-69
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

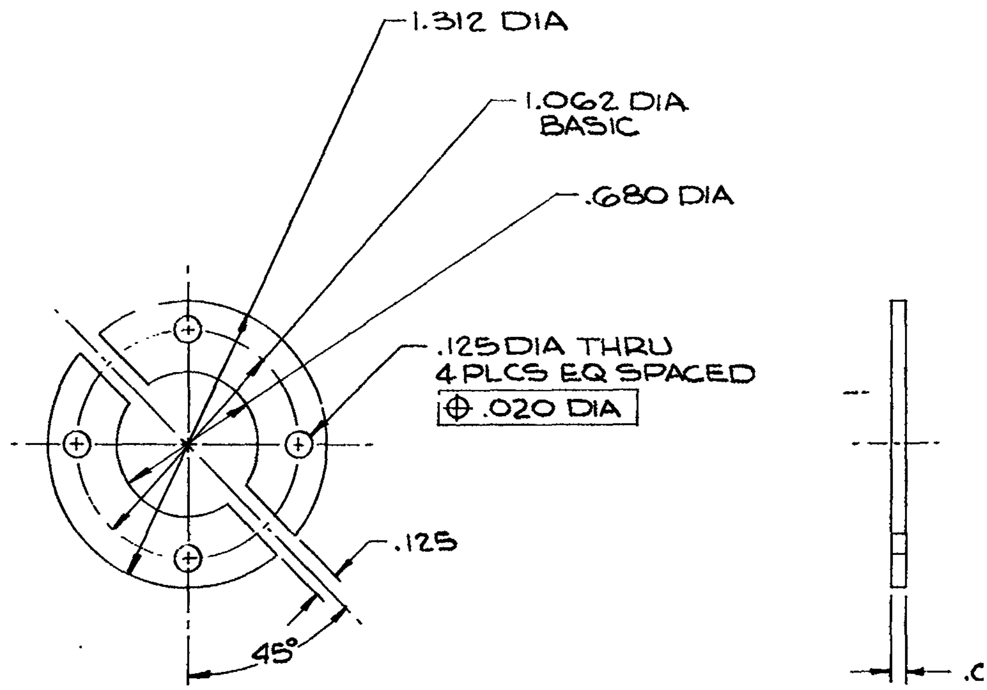
WASHER

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-238

SCALE 4/1 SHEET 1 OF 1

SYSTEMS 3000 REV. 1969

FOLDOUT FRAME 2



	-1	CLAMP			
CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE DESCRIPTION			

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

1 | PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GRP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT

CONTRACT NO.

DRAWN N. J. DAVE

CHECKED

STRUCTURES

MATL & PROCESS

ENGR

SUPERVISOR

OTHER APPROVALS

1. IDENTIFICATION MARKING PER PR 12-1

TYPE ____ CLASS ____

PART NUMBER ____

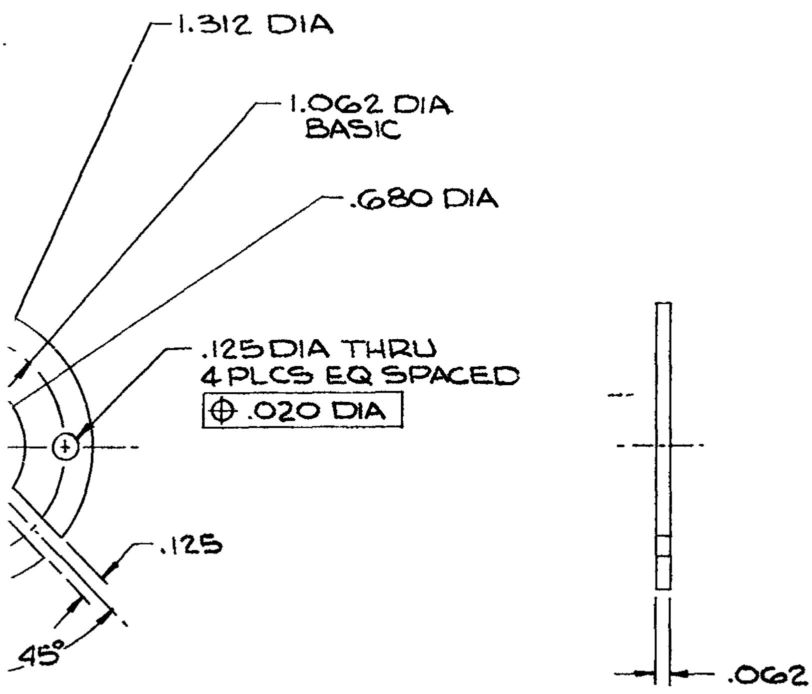
NOTES: UNLESS OTHERWISE SPECIFIED

USED ON	NEXT ASSY	NEXT ASSY QTY REQD
APPLICATION		

11/69 DIETERICH-POST CLEARPRINT 1000

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



SK4727-69-239

ITEM NO.	REF DES	SPEC.	MATERIAL	NOMENCLATURE OR DESCRIPTION	PART OR IDENTIFYING NO.	CODE IDENT NO.
			6061-T6 AL ALY	CLAMP	-1	

PARTS LIST

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

NEXT ASSY	QTY REQD
PR 12-1	1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125✓
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA

FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN	N.J. DAVENPORT	11-25-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[signature]	12-2-69
SUPERVISOR		

OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

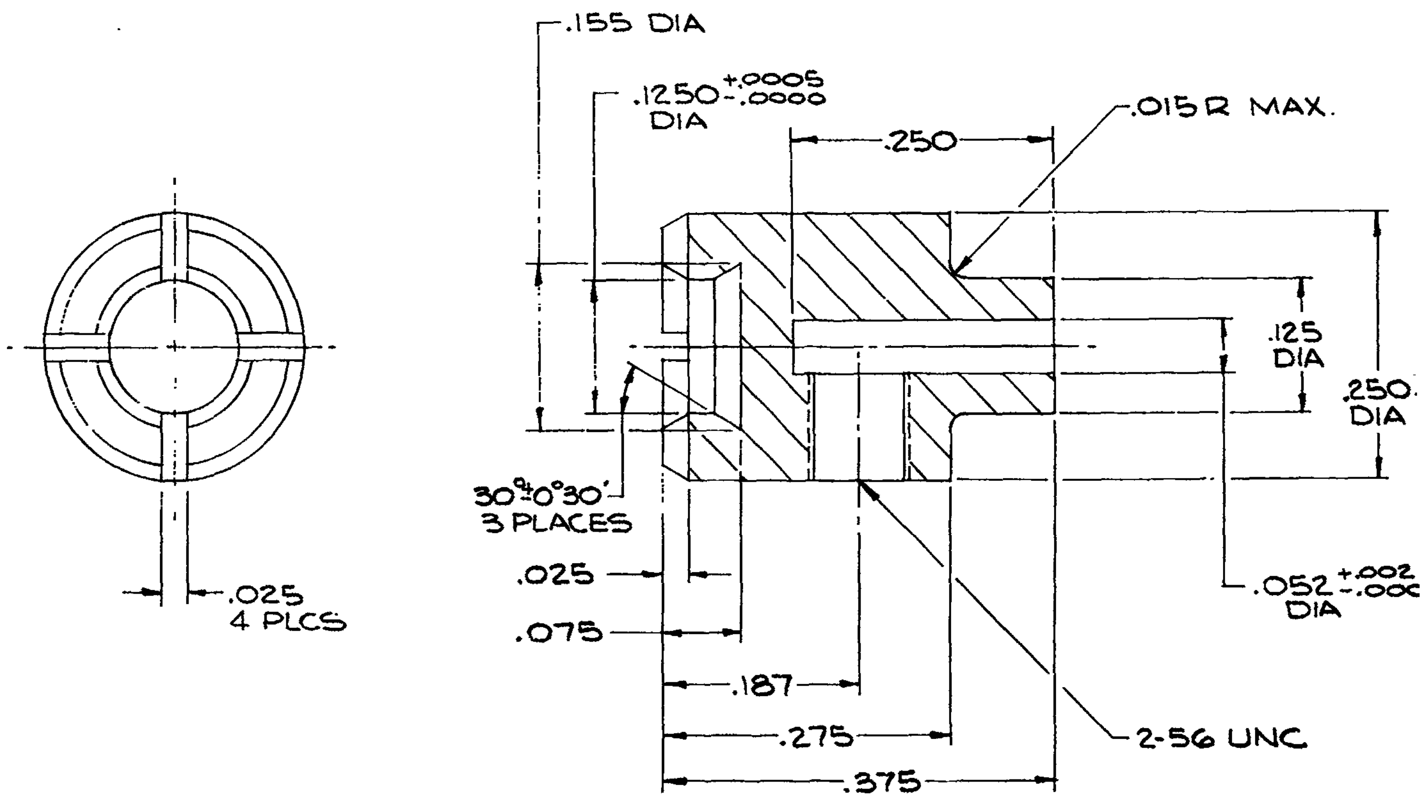
RING, CLAMP

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-239

SCALE 2/1 SHEET 1 OF 1

SYSTEMS 3400 REV. 1966

FOLDOUT FRAME



-2 DETAIL

AR	95272	2	BO
AR	95272	SR634-70	RUE
1		-2	POF
-1	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOME DE

QTY REQD PER ASSY CONFIGURATION

3. MOLD POPPET USING FIXTURE NO. SK4727-69-206.
2. BOND PER STILLMAN RUBBER CO. BONDING SPEC 1R3.
1. IDENTIFICATION MARKNG PER PR 12-1
TYPE ____ CLASS ____
PART NUMBER ____

NOTES: UNLESS OTHERWISE SPECIFIED

	SK4727-69-205	1
USED ON	NEXT ASSY	NEXT ASSY QTY REQD
APPLICATION		

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 64✓
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA

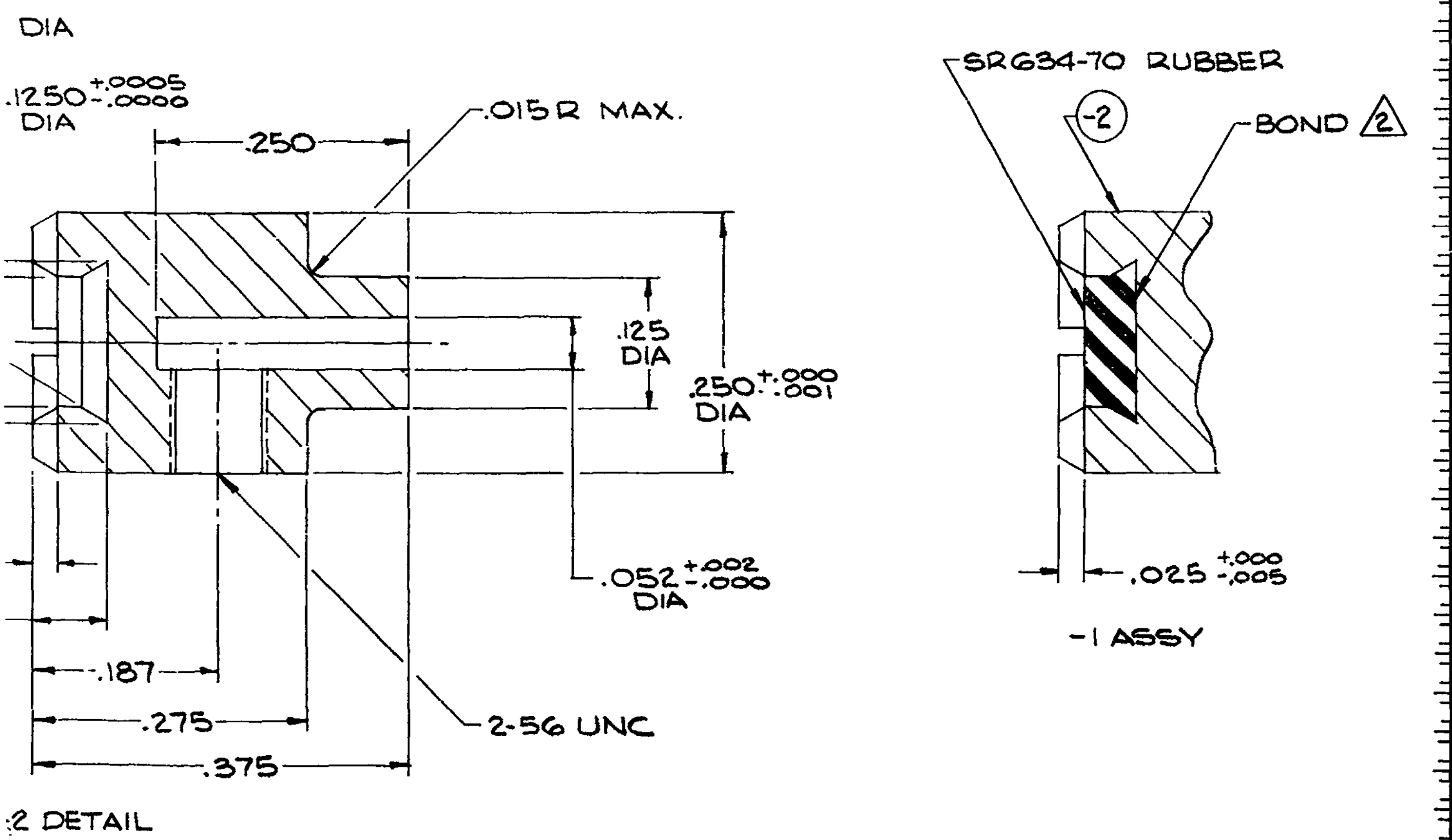
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	[illegible] −.001
.751	1.000	[illegible] −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT
CONTRACT NO.
DRAWN DAVEN
CHECKED
STRUCTURES
MATL & PROCESS
ENGR
SUPERVISOR
OTHER APPROVALS

6/64 DIETERICH-POST CLEARPRINT 1000

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



SK4727-69-202

AR	95272	2	BOND				
AR	95272	SR634-70	RUBBER	BUTYL			
1		-2	POPPET	303 CRES ROD			
-1	CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC	REF DES	ITEM NO.

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

9-205 | 1 | PR 12-1

ASSY | NEXT ASSY | QTY REQD

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 64
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 -.0005
.0145	.125	+.004 -.001
.126	.250	+.005 -.001
.251	.500	+.006 -.001
.501	.750	+.008 -.001
.751	1.000	+.010 -.001
1.001	2.000	+.012 -.001
OVER	2.000	+.015 -.005

DO NOT SCALE DRAWING

CONTRACT NO.		
DRAWN	DAVENPORT	10-6-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	M'Smith	10-10-69
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

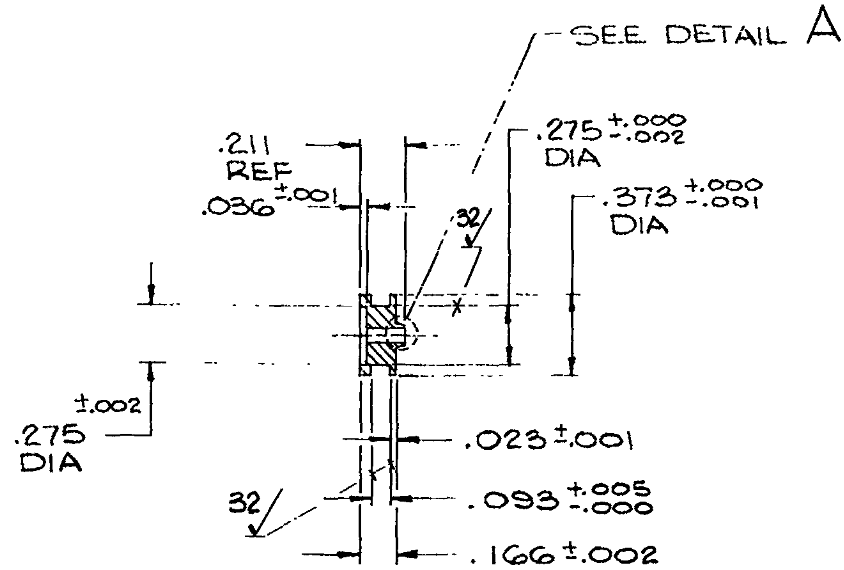
POPPET

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-202

SCALE 10/1 | SHEET 1 OF 1

SYSTEMS 3400C REV. 9-68

FOLDOUT FRAME 2



					-1	SEA
				CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCL DESCR

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 -.0005
.0145	.125	+.004 -.001
.126	.250	+.005 -.001
.251	.500	+.006 -.001
.501	.750	+.008 -.001
.751	1.000	+.010 -.001
1.001	2.000	+.012 -.001
OVER	2.000	+.015 -.005

DO

CONTRACT

DRAWN N.J.

CHECKED

STRUCTUR

MATL & PROCESS

ENGR

SUPERVISO

OTHER APPROVA

		1
USED ON	NEXT ASSY	NEXT ASSY QTY REQD
APPLICATION		

1. IDENTIFICATION MARKING PER PR 12-1

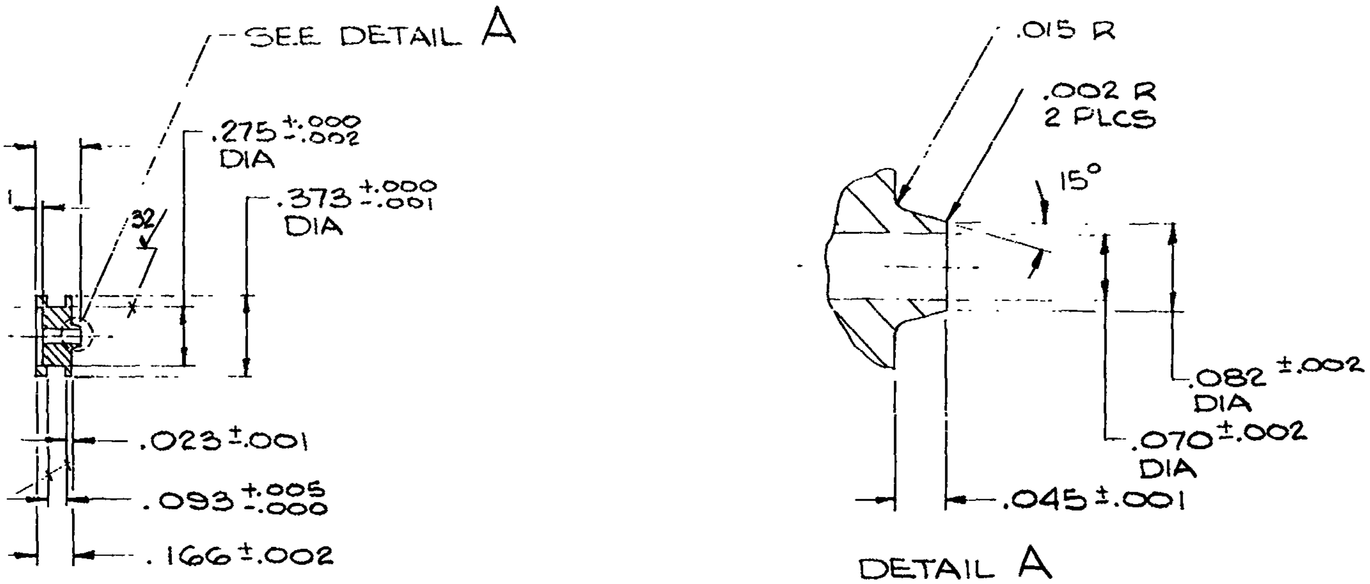
TYPE ________ CLASS ________

PART NUMBER ________

NOTES: UNLESS OTHERWISE SPECIFIED

FOLDOUT FRAME

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



DETAIL A
SCALE 10/1

SK4727-69-241

				CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC.	REF DES	ITEM NO.
					-1	SEAT	303 CRES			

QTY REQD PER ASSY CONFIGURATION

PARTS LIST

FINISH

HEAT TREAT

1		PR 121

NEXT ASSY QTY REQD

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS.
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT SCALE DRAWING

CONTRACT NO.		
DRAWN	N.J. DAVENPORT	11-25-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[illegible]	12-2-69
SUPERVISOR		

OTHER APPROVALS

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

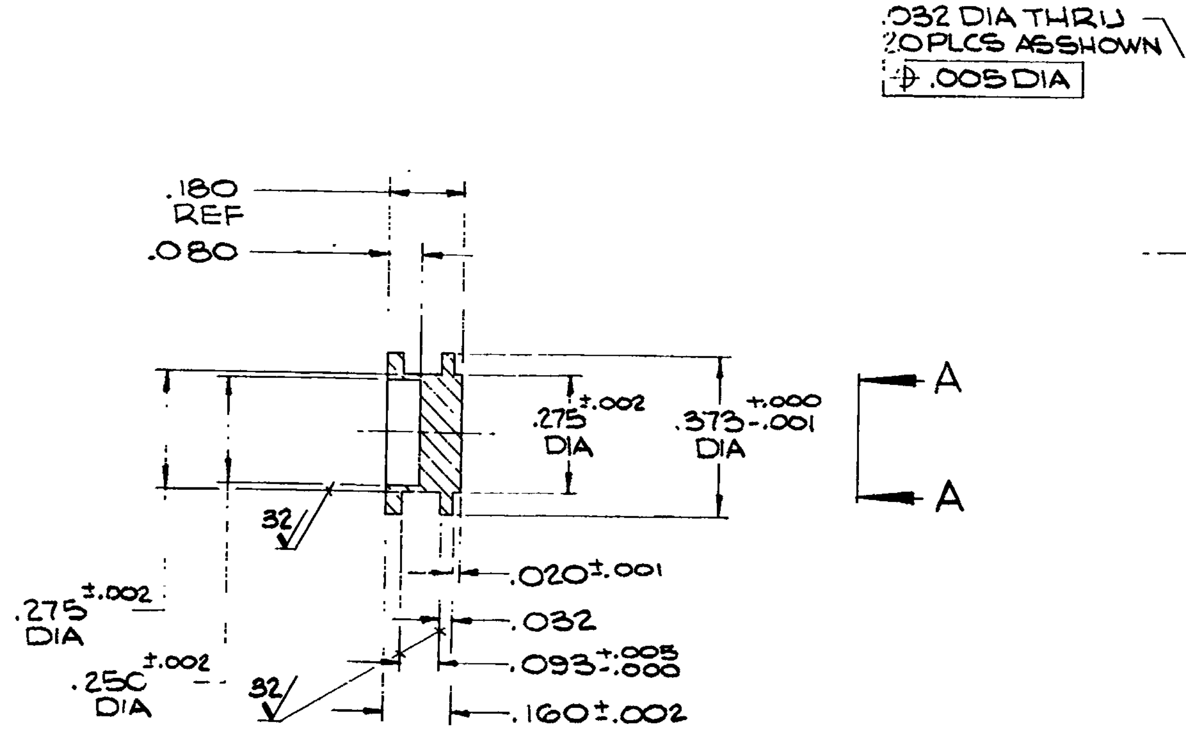
SEAT

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-241

SCALE 4/1 NOTED | SHEET 1 OF 1

SYSTEMS 3465 REV. 10-66

FOLDOUT FRAME



					-1	HEADER
				CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION

QTY REQD PER ASSY
CONFIGURATION

FINISH

HEAT TREAT

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS:
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 -.0005
.0145	.125	+.004 -.001
.126	.250	+.005 -.001
.251	.500	+.006 -.001
.501	.750	+.008 -.001
.751	1.000	+.010 -.001
1.001	2.000	+.012 -.001
OVER	2.000	+.015 -.005

DO NOT
CONTRACT NO.
DRAWN N.J. DAWS
CHECKED
STRUCTURES
MATL & PROCESS
ENGR
SUPERVISOR
OTHER APPROVALS

PR 12-1
APPLICABLE SPECIFICATIONS
THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

NEXT ASSY	USED ON	QTY REQD
		1

APPLICATION

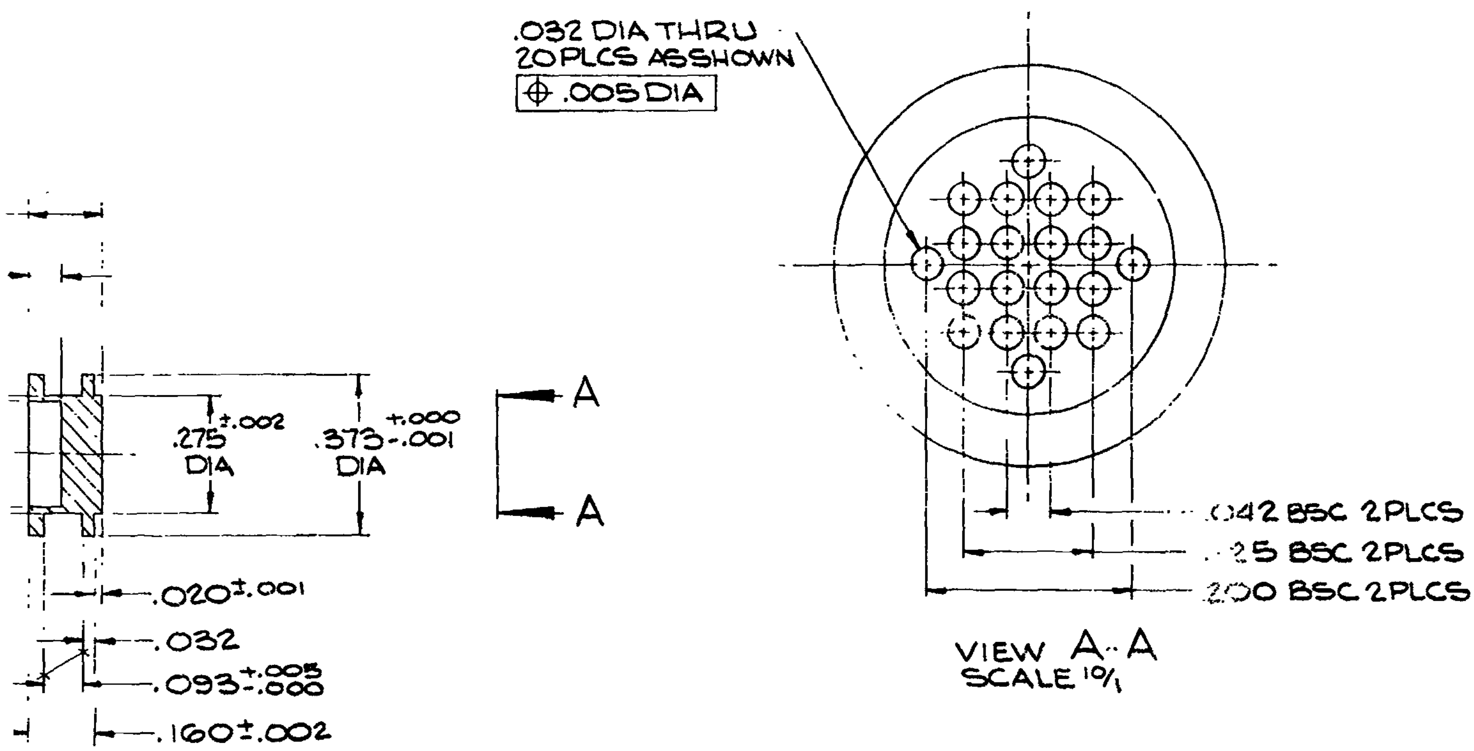
1. IDENTIFICATION MARKING PER PR 12-1
TYPE __________ CLASS __________
PART NUMBER __________

NOTES: UNLESS OTHERWISE SPECIFIED

11/69 DIETZGEN CLEARPRINT 1000

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



SK4727-69-242

			-1	HEADER	304 CRES			
		CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC.	REF DES	ITEM NO.

PARTS LIST

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

1	PR 12-1	
NEXT ASSY QTY REQD	APPLICABLE SPECIFICATIONS	...T ASSY

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125✓
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS: .XXX ± .010, .XX ± .03, .X ± .1

TOLERANCES ON ANGULAR DIMENSIONS: MACHINED & LOCATING ± 0°30', FORMED ± 2°, CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0005 -.0005
.0145	.125	+.004 -.001
.126	.250	+.005 -.001
.251	.500	+.006 -.001
.501	.750	+.008 -.001
.751	1.000	+.010 -.001
1.001	2.000	+.012 -.001
OVER	2.000	+.015 -.005

DO NOT SCALE DRAWING

CONTRACT NO.

DRAWN	N.J. DAVENPORT	11-25-68
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[signature]	12-2-69
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

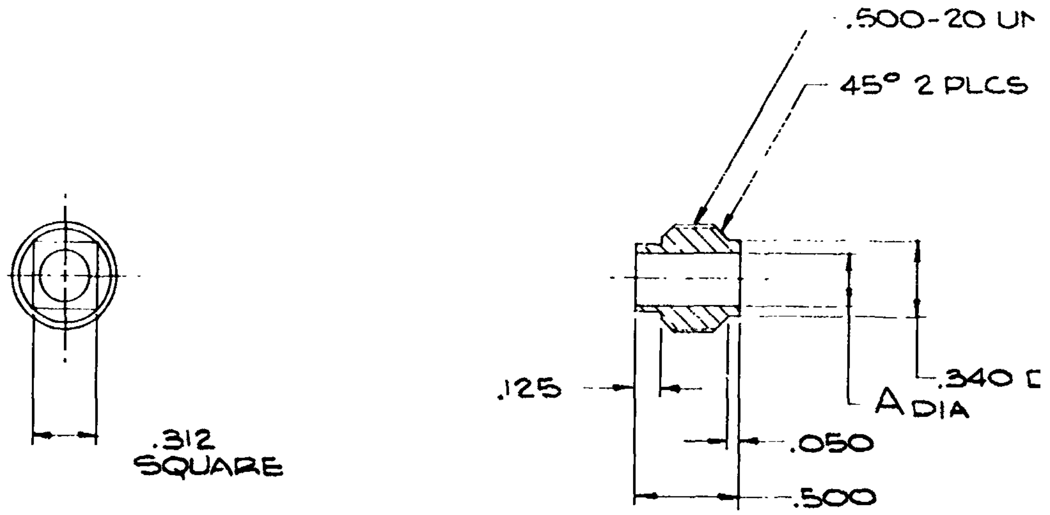
HEADER

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-242

SCALE NOTED — SHEET 1 OF 1

SYSTEMS 3400 REV. 10-66

FOLDOUT FRAME 2



DASH NO.	A DIA
-1	.250
-2	.260

CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENC DESC
	-2	NU
	-1	NU

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

	SK4727-69-205	1
USED ON	NEXT ASSY	NEXT ASSY QTY REQD
APPLICATION		

PR 12-1

APPLICABLE SPECIFICATIONS

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

TOLERANCES ON DECIMAL DIMENSIONS:
.XXX ± .010
.XX ± .03
.X ± .1

TOLERANCES ON ANGULAR DIMENSIONS
MACHINED & LOCATING ± 0°30'
FORMED ± 2°
CHAMFERS ± 5°

TOLERANCES - ALL HOLE DIA		
FROM	THRU	TOL.
UNDER	.0140	+.0020 −.0005
.0145	.125	+.004 −.001
.126	.250	+.005 −.001
.251	.500	+.006 −.001
.501	.750	+.008 −.001
.751	1.000	+.010 −.001
1.001	2.000	+.012 −.001
OVER	2.000	+.015 −.005

DO NOT S

CONTRACT NO.

DRAWN DAVEN

CHECKED

STRUCTURES

MATL & PROCESS

ENGR

SUPERVISOR

OTHER APPROVALS

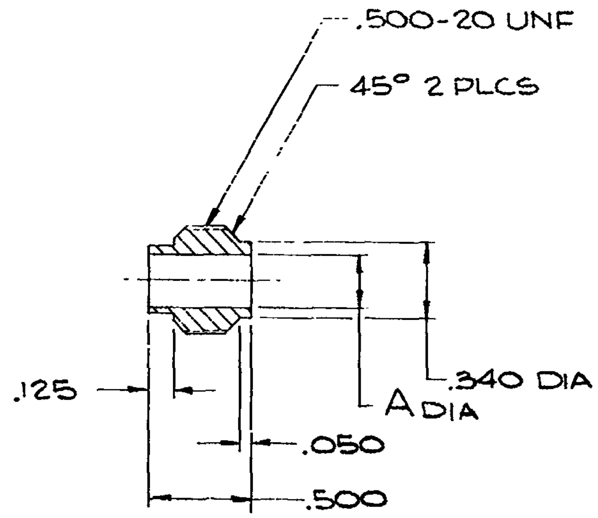
LT.
A

1. IDENTIFICATION MARKNG PER PR 12-1
TYPE ______ CLASS ______
PART NUMBER ______

NOTES: UNLESS OTHERWISE SPECIFIED

FOLDOUT FRAME 1

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	ADDED TAB. BLOCK DIA 'A' WAS .250 DIA	11-25-69	



SK4727-69-204 A

	-2	NUT	6061-T6 AL ALY				
	-1	NUT	6061-T6 A'. ALY BAR				
CODE IDENT NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPEC	REF DES	ITEM NO.	

PARTS LIST

QTY REQD PER ASSY CONFIGURATION

FINISH

HEAT TREAT

05	1		PR 12-1
NEXT ASSY	QTY REQD	APPLICABLE SPECIFICATIONS	

THE ABOVE TRW SYSTEMS GROUP SPECS FORM A PART OF THIS DRAWING

UNLESS OTHERWISE SPECIFIED
1. INTERPRET PER MIL-STD-100.
2. DIMENSIONS ARE IN INCHES
3. SURFACE TEXTURE SHALL BE 125
4. DIMENSIONS APPLY BEFORE PLATING OR CONVERSION COATING.
5. REMOVE BURRS & SHARP EDGES

	TOLERANCES - ALL HOLE DIA		
	FROM	THRU	TOL.
TOLERANCES ON DECIMAL DIMENSIONS:	UNDER	.0140	+.0020 -.0005
	.0145	.125	+.004 -.001
.XXX ± .010 .XX ± .03 .X ± .1	.126	.250	+.005 -.001
	.251	.500	+.006 -.001
TOLERANCES ON ANGULAR DIMENSIONS:	.501	.750	+.008 -.001
MACHINED & LOCATING ± 0°30'	.751	1.000	+.010 -.001
FORMED ± 2°	1.001	2.000	+.012 -.001
CHAMFERS ± 5°	OVER	2.000	+.015 -.005

DO NOT SCALE DRAWING

CONTRACT NO.		
DRAWN	DAVENPORT	10-6-69
CHECKED		
STRUCTURES		
MATL & PROCESS		
ENGR	[signature]	10-10-69
SUPERVISOR		
OTHER APPROVALS		

THE FOLLOWING EO'S HAVE BEEN ATTACHED TO THIS PRINT

TRW SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

NUT

SIZE	CODE IDENT NO.	
C	11982	SK4727-69-204
SCALE 2/1		SHEET 1 OF 1

SYSTEMS 3408C REV. 5-68

FOLDOUT FRAME 2

APPENDIX II. REGULATOR DEVELOPMENT TEST PLAN

1. INTRODUCTION

The testing outlined in this plan provides an evaluation of the functional characteristics of the regulator prior to assembly in the ammonia feed system. Tests are conducted using gaseous nitrogen for regulator operation. The tests involve separate characterization and optimization of the diaphragm, loading springs and the poppet seal. Finally, the complete regulator is pneumatically flow-tested in a test loop simulating the ammonia system. Flow rates simulating the predicted range of liquid and gaseous ammonia volumetric flows are applied over an inlet pressure range of 50 to 210 psi. Established standard acceptance proof, leakage, and flow tests are used.

2. TEST CONDITIONS

Pressure	
Inlet operating pressure:	50 to 210 psia
Regulated outlet pressure (nominal):	20 psid
Adjustable from 20 to 35 psid	
Proof:	315 psia inlet
	55 psia diaphragm
External leakage (total):	1×10^{-5} scc/sec GHe
Internal leakage at lockup:	0.3 scc/hr GN_2
Flow range	
Maximum flow:	68 SCFH GN_2 at 66 psia inlet pressure
Minimum flow:	2 SCFH GN_2 at 210 psig inlet pressure
Temperature:	Laboratory ambient

3. TEST REQUIREMENTS

3.1 DEVELOPMENT TESTING

3.1.1 Diaphragm Function

Assemble diaphragm and loading spring assembly. Install in test setup, shown in Figure 78.

a. Pressure strength

   Apply proof pressure, inspect for damage or change in dimension.

b. Effective area over operating range

   Measure force output relative to diaphragm position and applied pressure.

c. Hysteresis

   Measure force output variation with direction of diaphragm motion.

3.1.2 Poppet Valve Function

a. Seal friction

   Measure shaft seal friction with and without pressure.

b. Poppet pressure unbalance

   Measure unseating force required as a function of pressure.

c. Poppet leakage

   Measure nitrogen and helium leakage rates.

3.1.3 Regulator Performance

Completed regulator assembly. Install in flow test system, Figure 79. Establish the regulator pressure control characteristics over the following range of conditions:

a. Calibration range

   Determine attainable control pressure over the spring adjustment range.

b. Effect of inlet pressure variation on regulation

   Observe the effect of varying the inlet pressure over the operating range on regulated pressure.

c. Effect of flow rate on regulation

   Vary the nitrogen flow by adjusting the downstream metering valve. Observe the effect on regulated pressure.

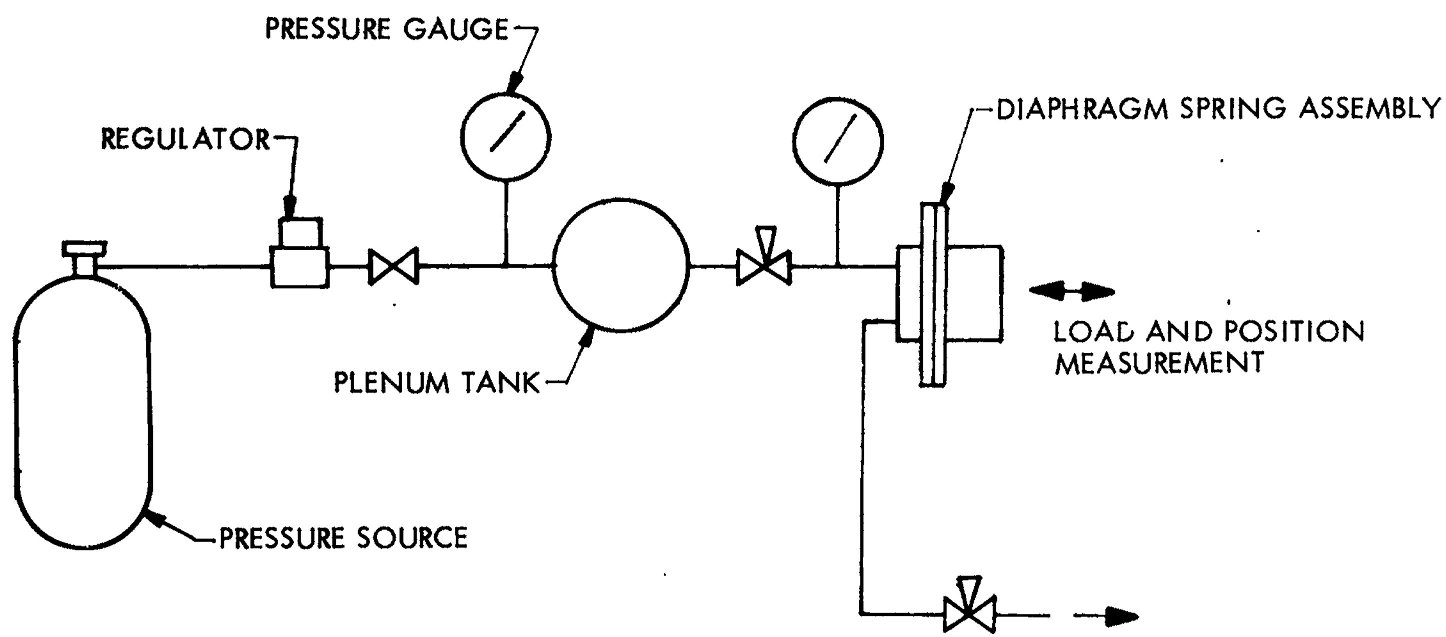


Figure 78. Diaphragm and Valve Poppet Functional Test Schematic

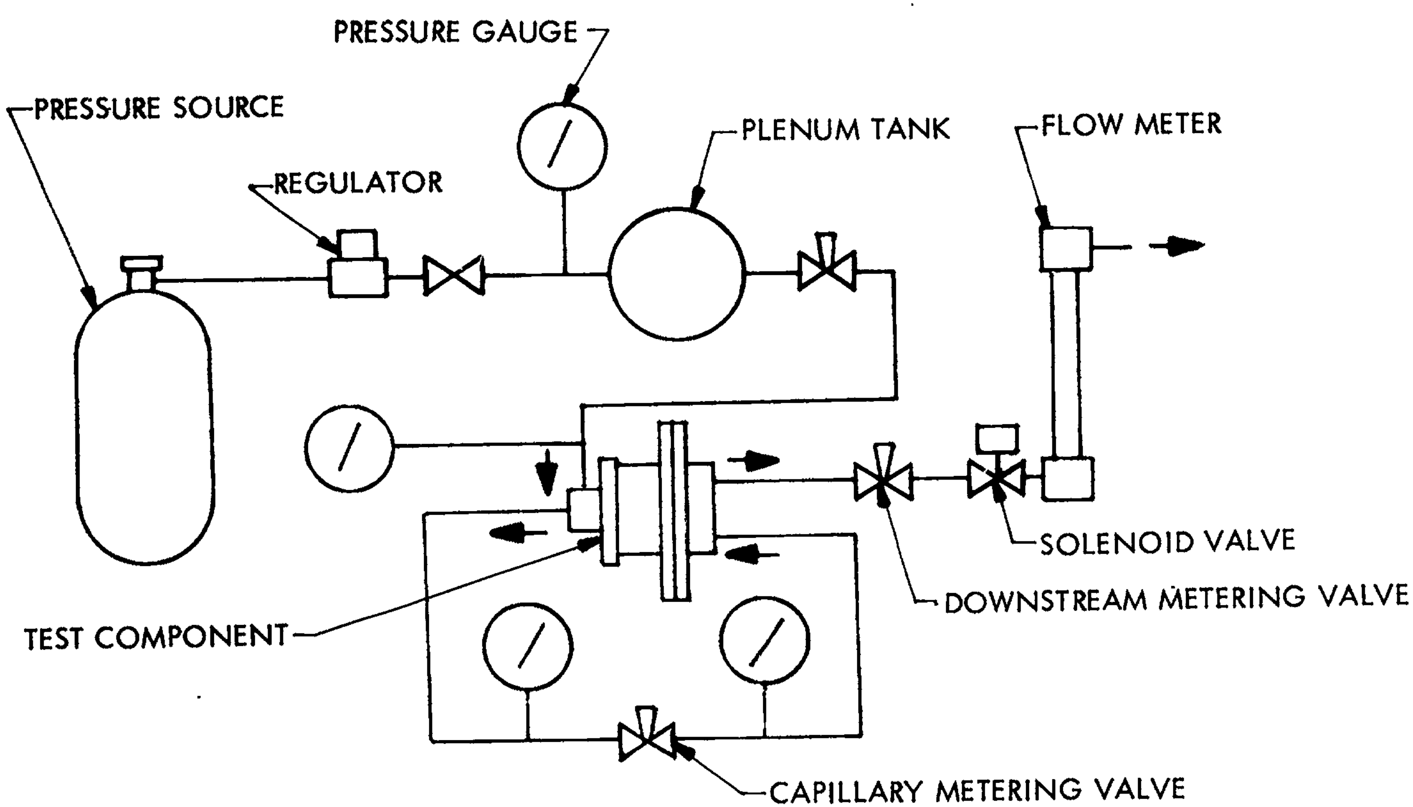


Figure 79. Regulator Performance Test Schematic

d. Effect of varying simulated capillary restriction
   With the downstream metering valve set at a nominal flow, observe the effect on regulation of throttling the capillary metering valve.

e. Stability and lockup pressure
   Determine the effect of opening and closing the downstream solenoid valve on regulated pressure by varying the metering conditions as in paragraphs c and d above. Observe stability characteristics and lockup pressures.

3.2 ACCEPTANCE TEST

The following tests will be applied when required to establish normal operation of the regulator prior to installation on the ammonia system.

a. Pressure calibration
   With the regulator installed in the flow system, Figure 79, set regulated pressure as required.

b. Lockup and restart
   By operating the downstream solenoid valve, determine normal lockup and restart characteristics.

c. Proof
   Apply proof pressure to the valve and diaphragm assemblies, respectively. Hold for two minutes. Observe damage or permanent deformation.

d. Internal leakage
   Determine nitrogen leakage through the valve poppet on lockup.

e. External leakage
   Determine helium leakage by the mass spectrometer bell jar method.

APPENDIX III. PROTOTYPE REGULATOR ACCEPTANCE TEST PROCEDURE

TEST SCHEDULE

a. Pressure calibration

(Regulator is installed in test system shown in Figure 80.)

With a flow rate of 2 SCFH at an inlet pressure of 210 psig, set the regulated pressure at 20 $\pm$ .05 psig.

Regulated pressure 20.05 psig.

b. Lockup pressure

With flow set at 68 SCFH and at an inlet pressure of 210 psig, shutoff downstream solenoid valve. Lockup pressure shall not exceed 0.6 psi above regulated pressure set at Step a.

Maximum allowable lockup pressure: 20.65 psig.

Observed lockup pressure: 20.4 psig.

c. Proof pressure

Apply specified gaseous nitrogen proof pressure separately to diaphragm and valve assemblies of regulator. Hold pressure for 2 minutes. No damage or yielding allowable.

	Required Pressure PSIG	Pressure PSIG	Time Min.
Diaphragm	55	55.0	2
Valve	315	315.0	2

d. Internal leakage

(Regulator is installed in test system shown in Figure 81.)

Apply 25 psig gaseous nitrogen to the regulator diaphragm and 210 psig to valve inlet. With valve outlet tube immersed in distilled water, observe leak rate over 30-minute period.

Leakage: 0.0 cc/hr.

e. External leakage

(Regulator is installed as shown in Figure 82.)

Pressure leakage

Install regulator in bell jar. Separately leak check the diaphragm then the valve assembly to noted pressures with helium. Observe for 3 minutes for each test using mass spectrometer.

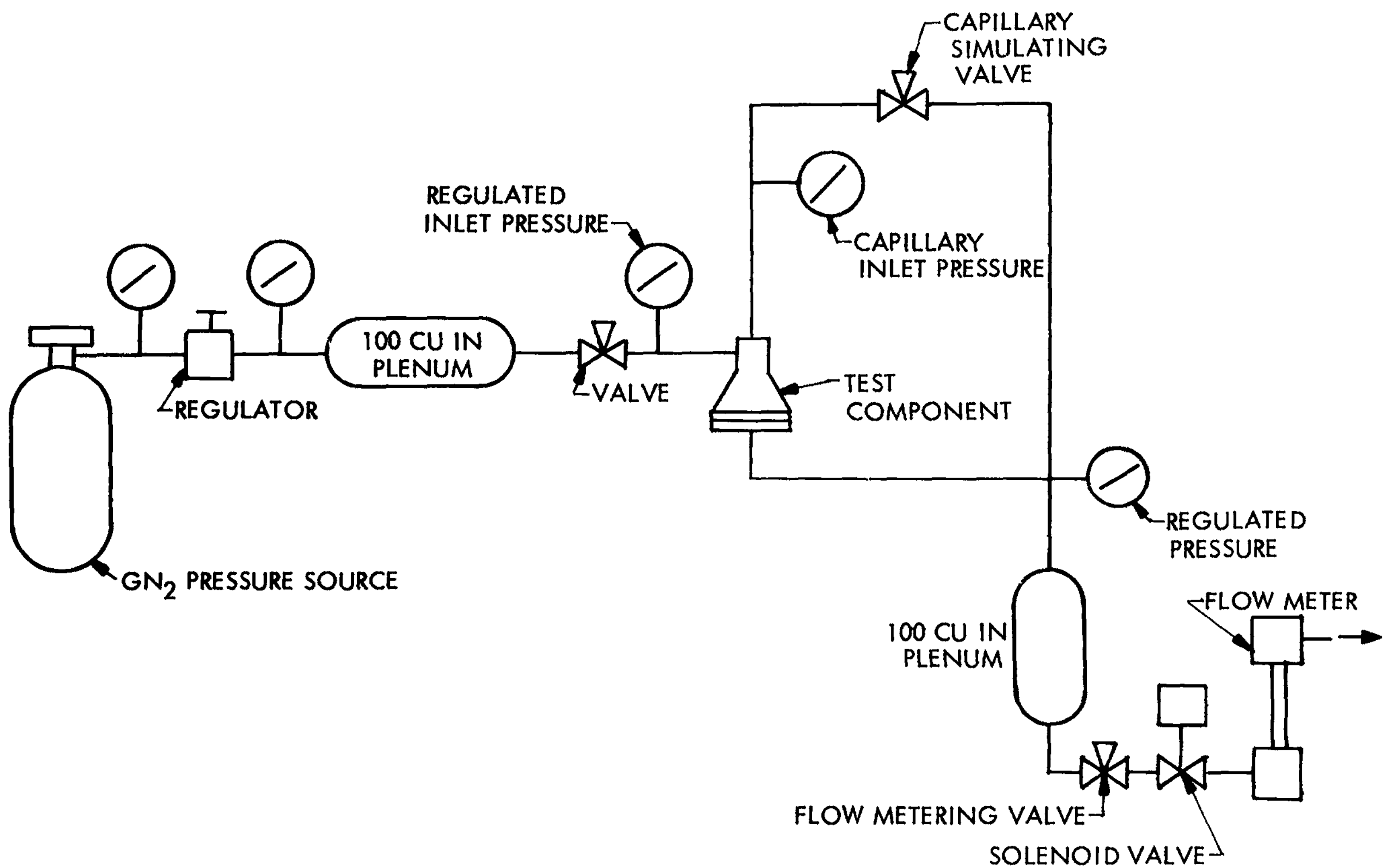


Figure 80. Regulator Calibration Test Schematic

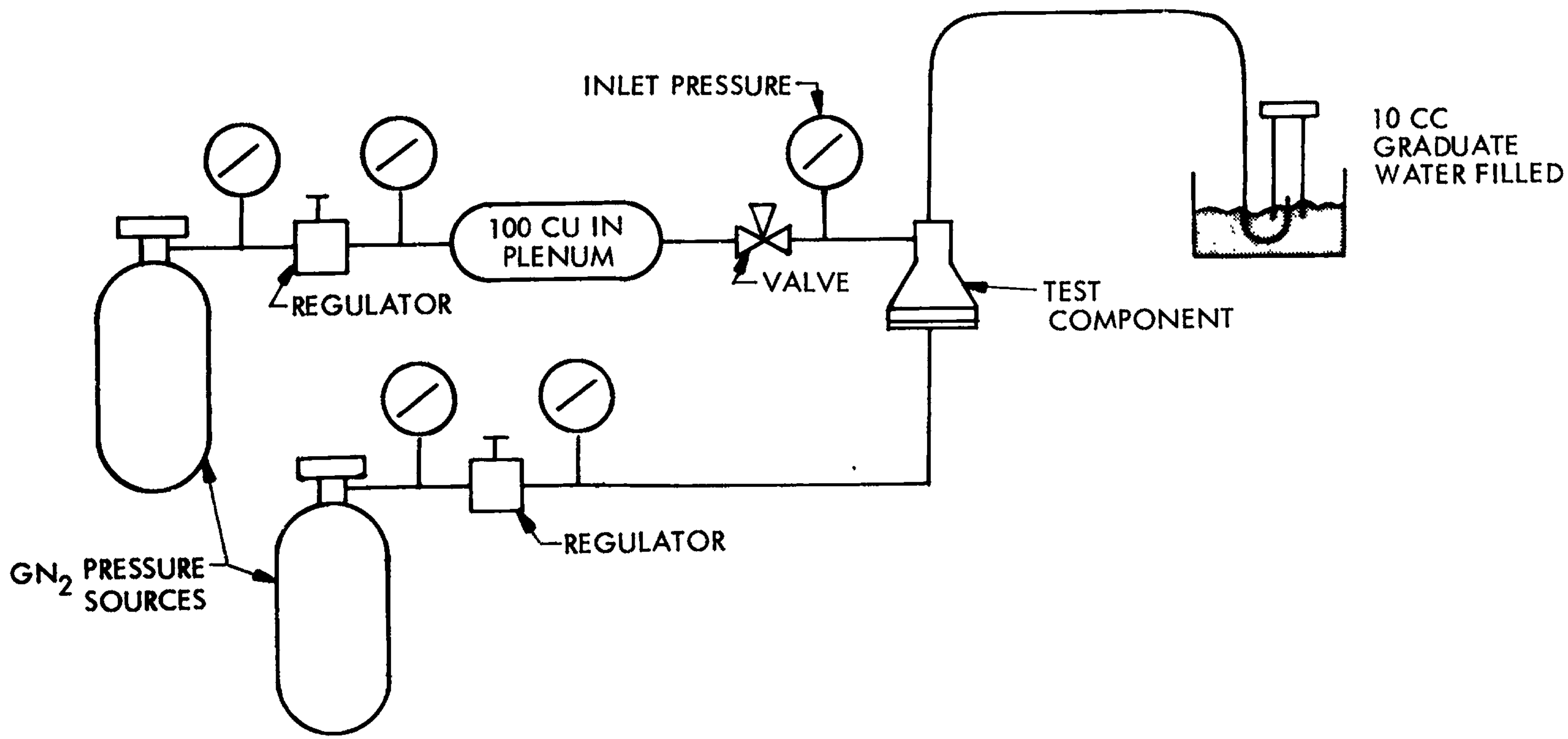


Figure 81. Regulator Internal Leak Test Sehematic

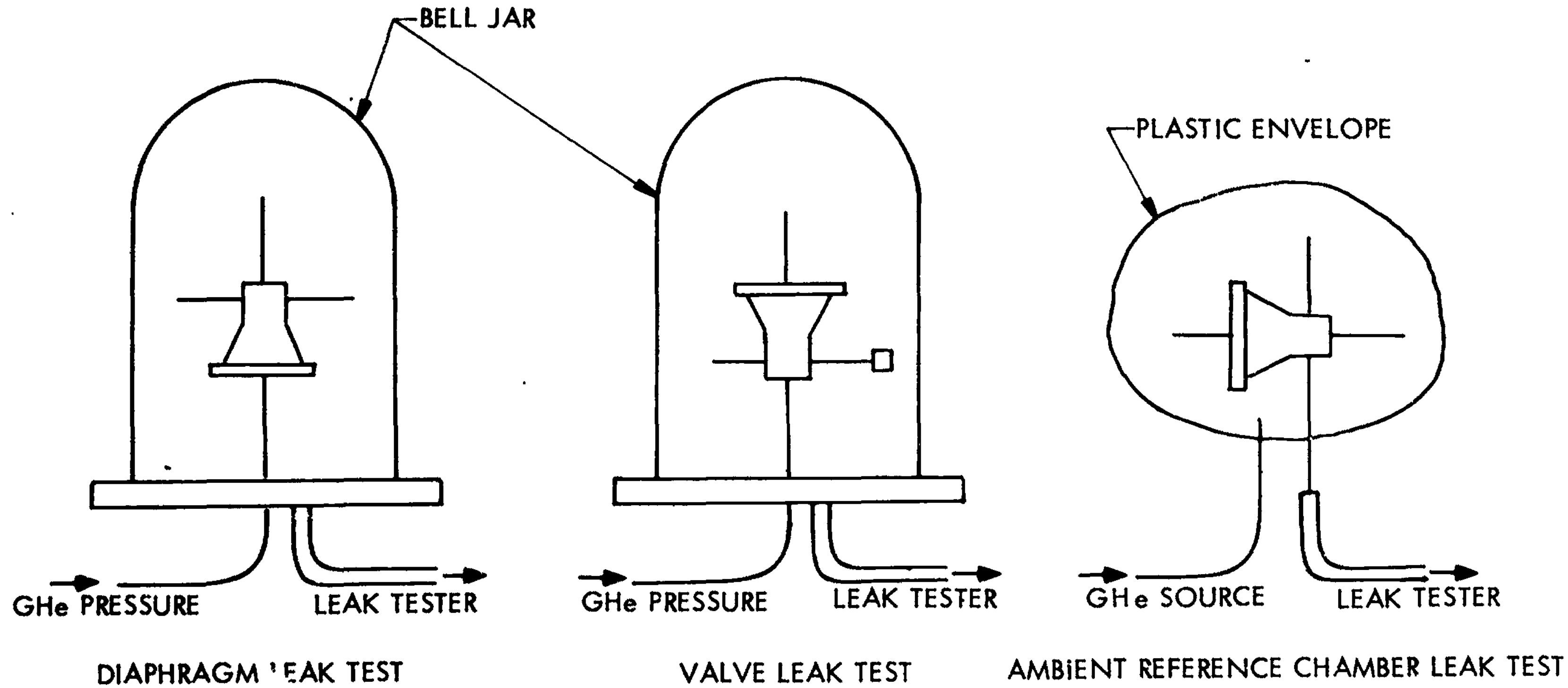


Figure 82. Regulator External Leak Test Schematic

	Required Pressure	Pressure PSIG	Leakage Std. cc/sec Helium
Diaphragm	35	35.0	68×10^{-8}
Valve	210	210.0	30×10^{-8}

f. Pressure-drop test

(Regulator is installed in test setup as shown in Figure 83.) With regulator held at a constant inlet pressure flow gaseous nitrogen through the unit at the following flow rates:

Inlet Pressure P_1-PSIG		Flow-SCFH		Pressure Drop
Reqd.	Actual	Reqd.	Actual	PSID
51	51.0	10	10.0	Negligible
51	51.0	20	20.0	Negligible
51	51.0	30	30.0	0.5
51	51.0	40	40.0	1.2
51	51.0	50	50.0	1.9
51	51.0	60	60.0	2.9
51	51.0	68	68.0	3.7
51	51.0	70	70.0	4.0
51	51.0	80	80.0	5.2

g. Repeat Step a.

Regulated pressure: 20.05 psig.

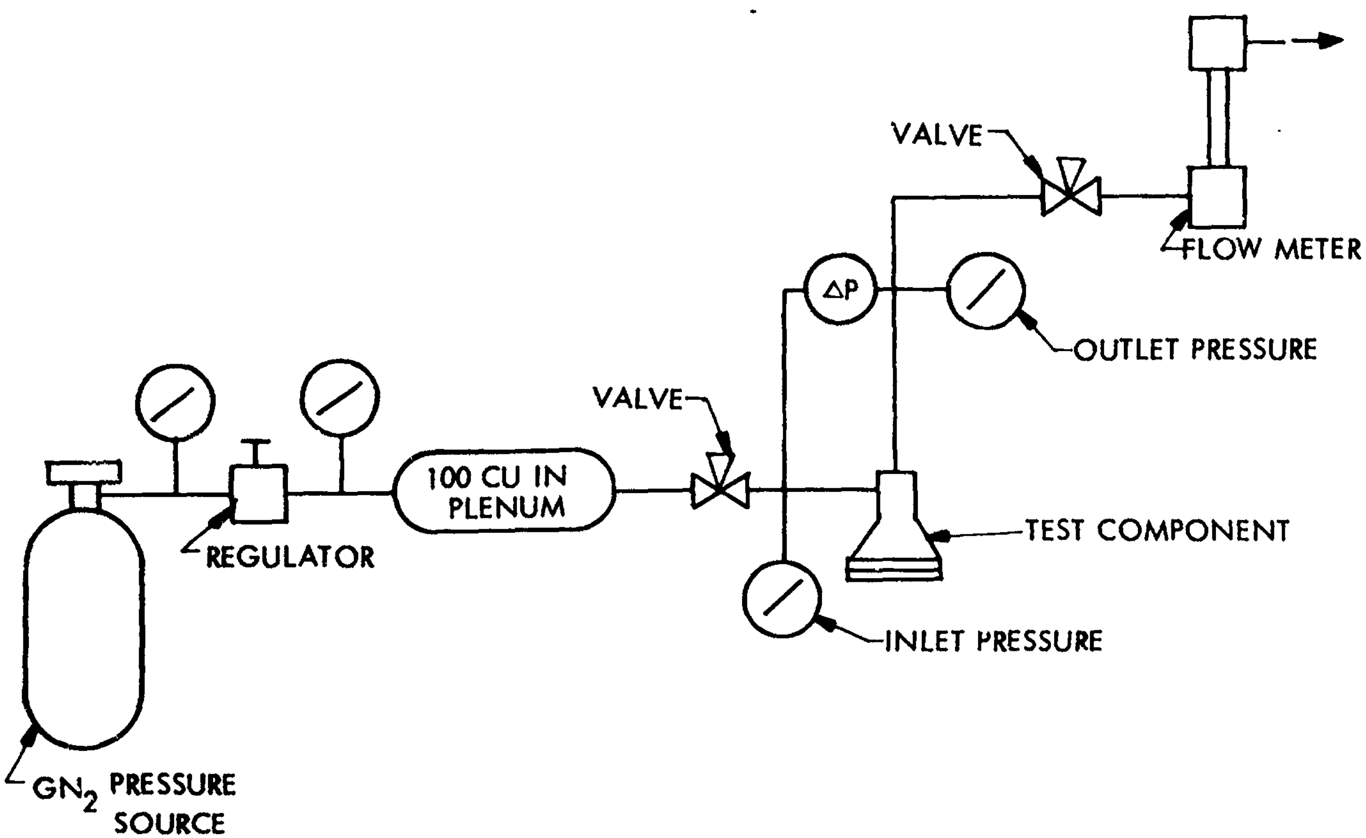


Figure 83. Regulator Pressure Drop Test Schematic

APPENDIX IV. FLIGHT REGULATOR ACCEPTANCE TEST PROCEDURE

TEST SCHEDULE

a. Pressure calibration

(Regulator is installed in test system shown in Figure 80.)
With a flow rate of 2 SCFH at an inlet pressure of 210 psig, set the regulated pressure at 20 ± .05 psig.

Regulated pressure: 20.00 psig.

b. Lockup pressure

With flow set at 68 SCFH and at an inlet pressure of 210 psig, shutoff downstream solenoid valve. Lockup pressure shall not exceed 0.6 psi above regulated pressure set at Step a.

Maximum allowable lockup pressure: 20.60 psig.

Observed lockup pressure: 20.30 psig.

c. Proof pressure

Apply specified gaseious nitrogen proof pressure separately to diaphragm and valve assemblies of regulator. Hold pressure for 2 minutes. No damage or yielding allowable.

	Required Pressure PSIG	Pressure PSIG	Time Min.
Diaphragm	55	55.0	2
Valve	315	315.0	2

d. Internal leakage

(Regulator is installed in test system shown in Figure 81.)
Apply 25 psig gaseous nitrogen to the regulator diaphragm and 210 psig to valve inlet. With valve outlet tube immersed in distilled water, observe leak rate over 30-minute period.

Leakage: 0.0 cc/hr

e. External leakage

(Regulator is installed as shown in Figure 82.)

Pressure leakage

Install regulator in bell jar. Separately leak check the diaphragm then the valve assembly to noted pressures with helium. Observe for 3 minutes for each test using mass spectrometer.

	Required Pressure PSIG	Pressure PSIG	Leakage Std. cc/sec Helium
Diaphragm	35	35.0	8.7×10^{-7}
Valve	210	210.0	1.4×10^{-5}

Vacuum leakage

Connect helium leak detector to the diaphragm reference fitting. Apply a vacuum through the leak detector. Flood helium around the regulator. Record the observed leakage.

Observed leakage: 8.7×10^{-8} std. cc/sec. helium.

f. Pressure drop test

(Regulator installed in test setup as shown in Figure 83.) With regulator held at a constant inlet pressure flow gaseous nitrogen through the unit at the following rates:

Inlet Pressure P_1-PSIG		Flow-SCFH		Pressure Drop
Reqd.	Actual	Reqd.	Actual	PSID
51	51.0	10	10.0	Negligible
51	51.0	20	20.0	.15
51	51.0	30	30.0	.35
51	51.0	40	40.0	.7
51	51.0	50	50.0	1.0
51	51.0	60	60.0	1.5
51	51.0	68	68.0	1.9
51	51.0	70	70.0	2.0
51	51.0	80	80.0	2.6

g. Repeat Step a.

Regulated pressure: 20.00 psig.